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ANTS

By JULIAN HUXLEY

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ANTS

CHAPTER I

INTRODUCTORY

The social insects in general, and ants in particular, are, with birds and with man, the fine flowers of the tree of life. Had not their advance to greater size and strength been checked through limitations inherent from the first in the fundamentals of insect organization, they might well have evolved into beings so formidable as to have held the vertebrates back in their conquest of the land, and for ever prevented the development of man.

Innumerable comparisons have been made between human society and the social organization of ant, bee, or termite; theories have been advanced and morals pointed, Utopian schemes encouraged and whole theories of the State built up for man on the basis of analogy with these little insects. Almost without exception the moral has been false, the analogy used misleadingly. It will be well to point out at the start some of the radical differences between social insects and social man.

In the first place, the development from non-human to human mammal has occurred but once,* while the

* There are still one or two authors who uphold the polyphyletic, or multiple, origin of man. It is, however, extremely improbable that they are right; and even if they were, they only suppose that the different races of man have evolved from different types within the one small group of anthropoid apes. The multiple origin of social insects is an origin from a number of quite separate and radically different orders or sub-orders, as different as rodent from carnivore, as elephant from ruminant.

transition from non-social to social insects has occurred on a number of separate occasions. Three main grades of social habit may be distinguished. In the lowest there is some sort of a family life, either the mother or both parents living with and helping the developing young. This may be called the subsocial, or family, grade. The second is the true social, or colonial, grade, in which the young, when fully grown, stay with their parents and co-operate with them in building the nest and caring for further broods of young. The highest grade is that of the caste-society, in which some of the young are transformed into unsexed "neuters," who take off the shoulders of the fertile caste all the duties of the colony, save only that of reproduction.

According to W. M. Wheeler, the great authority on the biology of these animals, some grade of social life has been reached no less than twenty-four times in the evolution of insects, among the representatives of five separate orders. If we deduct the merely subsocial types, ten separate attainments of the true social level remain, distributed between the orders of Hymenoptera and Isoptera. Among the Hymenoptera, Wheeler believes that full social life has been acquired five separate times by wasps, three times by bees, and once by ants. Even if we suppose that ants—all members of which are social—arose as an offshoot of an already socialized wasplike form, it is at least certain that bees and wasps have developed their extremely similar societies quite independently of each other; and, in addition, the caste-system has been evolved at least two or three separate times in wasps, and at least twice among bees; finally, the Termites have developed social life and a caste-system quite separately from the Hymenoptera, and along rather different lines.

An even more striking difference between social insects and man concerns the number of species of the two types which exist. There is but one human species

now extant. Even if we take all known fossil forms into account, we can only muster half a dozen at the most. Of fully social insects, on the other hand, there have been described about 800 species among wasps, about 500 among bees, over 3,500 among ants, and over 1,000 among termites—nearly 6,000 in all; and when we reflect that systematists are discovering scores of new species, notably from the Tropics, every year, we shall probably not be making an over-estimate if we say that 10,000 separate species of social insects are in existence.

The reason for this is partly, though not mainly, to be sought in another biological difference between man and the social insects. Man dates back certainly no earlier than the Pliocene;* and *Homo sapiens* appears to have arisen only during the Pleistocene, less than one million years ago. Social ants, bees, wasps, and termites have all been found in Baltic amber, which exuded from pines growing in what to-day we call Sweden, right back in Lower Oligocene times, about thirty million years ago. In Wheeler's own words, "My study [of these ants trapped in that long-ago resin] showed conclusively that the ants have undergone no important structural modifications since the Lower Oligocene, that they had at that time developed all their various castes . . . that they attended plant-lice, kept guest beetles in their nests, and had parasitic mites attached to their legs in the very same peculiar position as in our living species." Many modern genera were already in existence, and some of the Oligocene species were practically indistinguishable from those of to-day. Typical ants have been found in the Eocene, and the strong probability is that several branches of the Hymenoptera became fully social at least as early as the Cretaceous.

* The geological periods mentioned are arranged in the following order, from the present back: Pleistocene, Pliocene, Miocene, Oligocene, Eocene, Cretaceous, Jurassic, Triassic.

Even if we take Upper Cretaceous and Lower Pliocene as the two dates in question, social insects have been in existence well over five times as long as even the most primitive man; and the ratio, if we take the Triassic for the ants, and the Old Stone Age for man, becomes more like a hundred times.

This difference in evolutionary past has another aspect. We have just seen that the societies of ants have changed extremely little since the Oligocene, about thirty million years ago. But we all know that the societies of man have changed profoundly since man's origin, and, what is more, that the change shows no sign of abating into a stable phase, but has, rather, been progressively accelerated throughout man's history. This points the way to the last and most fundamental distinction of all, on which all the others hinge —the difference in the very structure of the societies and in the whole type of behaviour of the two kinds of organism. The insect imago, or adult, appears upon the scene full-grown, with a full complement of diverse instincts, and does not require any teaching to be able to carry out all the duties biologically required of her. True that she possesses a quite definite, if restricted, power of learning, but this enables her rather to adapt her instinctive behaviour to this or that detailed difference of the environment, not to ascend to wholly new levels of behaviour. Furthermore, the major part of the division of labour in an insect society is predetermined by the structure of body and brain. Usually the different castes are of different structural pattern. The smallest neuters of many legionary ants are several hundred times less bulky than the males or females, as well as being of quite different appearance, those of Carebara well over a thousand times; the head of the soldier of the harvesting ant Pheidole is bigger than all the rest of the animal put together, while in the worker it is of normal proportions. The worker bee not only has a larger brain than the queen, but has her legs

equipped by heredity with all the tools and gadgets needful for collecting and carrying pollen. Occasionally a division of labour is secured by means of a succession of different instincts in time. The young worker honey-bee helps tend the brood, but there comes a time when she abandons this and begins collecting nectar and pollen. This change of habit has nothing to do with learning, but depends on some development within the brain as definitely as does the change from tadpole into frog depend on material changes in the body.

On the other hand, by far the greater part of division of labour in human society is not predetermined through inborn structure, but is the result of learning. Even where a caste-system has been in operation for centuries, it has had negligible effects upon man's all-round capabilities. Man does not find his tools growing upon his body; he has to make them in infinite variety. His instincts are less specific than the insects', and are gradually overlaid by habit, experience and intelligent purpose until all trace of the original purely instinctive actions are supplanted by learnt behaviour, often of wholly new type, the instinct being merely the buried conduit along which the impulse to action must flow for part of its course. And finally man alone among animals has come to possess conceptual thought and a cumulative tradition. It is this cumulative tradition, based upon rapid learning and conceptual thinking, which has allowed human society to make such rapid evolutionary progress. What is more, the plasticity thus gained has made it possible for man to exploit all the regions of the globe, from Greenland to the tropical jungles, from the Sahara to the Alps, and to reap the advantages of the most varied modes of life, from miner to office clerk, fisherman to factory worker, while still remaining contained within the limits of a single biological species. The social insects achieve the same result, of exploiting

the most diverse geographical regions and ways of life, but they can only do so by quite other means. Since their achievement is based almost wholly on ready-made structure, whether the obvious structure of bodily tools, or the concealed but none the less real nerve-structure which is the physical basis of instinct, they can only adapt themselves to large changes of surroundings or way of life by means of alterations in their inherited construction. In other words, they must rely for their adaptations on mutations in their hereditary constitution, which is, of course, in the absence of further mutations, fixed and stable. Thus, while in man each new mode of life requires only a new habit and tradition flowering out of the old germ-plasm, in the insect it demands a new species with changed germ-plasm. The social insects thus exploit the world as a group of separate species, uncombinable biological units, man as a single biological unit, the separateness of whose minor groups is in the main transitory and preventable.

This difference is a particular case of a general principle of evolution. Wherever there exists specialized detailed adaptation, whether of bodily structure or behaviour, there we find groups with a great multiplicity of separate species; wherever structure or behaviour is either generalized or plastic, there we find fewer species in the group. This principle works both when specialized are contrasted with primitive groups, and when they are contrasted with progressive but plastic forms.

To take the contrast of specialized with primitive, there are many more species of bony than of gristly fish, of Pliocene mammals than of Eocene mammals, of insects than of Annelid worms. If we contrast less plastic with more plastic, there are many more birds than mammals, and this again in spite of the birds' greater mobility; more snails than cuttlefish and octopuses, more monkeys than apes. Finally, man, on account of

his almost unlimited plasticity, takes living matter on to a new level, where the most extensive adaptation can be achieved, and the whole group yet remain constituted by a single species. Man and the insects thus make the most complete contrast in this respect—the two most successful biological groups in existence, one consisting of nearly half a million kinds, the other but of one. And this consequence is in the long run a cause of the limitation of progress in the less plastic, of further progress in the more plastic.

There is every reason for believing that ants have long since reached the highest level possible to them, and equally every reason for believing that man is only at the bottom of his evolutionary ladder.

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CHAPTER II

THE ANT STATE

The ants are of all the social insects the most successful and perhaps the most extraordinary. All their more than 3,000 species are social, and show caste-differences, although their societies vary enormously both in size and complexity. Some species boast no more than a few dozen individuals to a nest, whereas in forms like Atta a single colony may muster half a million.

Ants (save a few monstrous queens, sluggish and bloated with eggs) never attain the individual size of some wasps and bees. Even the largest neuter ants fall far short of a gram in weight; in other words, it would take well over a hundred thousand of them to outweigh an average man. The range of adult ant-

size, however, is much greater than that of man. Even if we include dwarfs at one end and monstrosities of fat at the other, the largest human being weighs not more than twenty-five or thirty times as much as the smallest; while if we include normal specimens the figure will be reduced to under ten times. But the tiniest ants, like the smallest workers of Carebara, weigh several thousand times less than their largest relatives. Even in one and the same colony, individual bulk may vary up to a thousand times, as in Carebara again, or nearly to the same extent as if Lilliput were sober truth, and Lilliputians and normal men and women lived side by side in one community.

The dwellings of ants are usually underground, and are always characterized by great irregularity of construction as compared with those of bees or wasps. Gone are the honey cells, gone the separate room for each grub. What remains is an irregular series of chambers, connected with each other and the exterior by an equally irregular series of passages. Owing to this lack of geometrical precision, their constructions are less immediately interesting to us; none the less, their irregularity is really a sign of evolutionary advance, for it means that their habits are much more plastic and adaptable, and that, if conditions become unfavourable, the old nest can be abandoned and a new one constructed with a minimum of time and labour. The same is true of their care of their young. The young have no fixed and permanent cribs, but are carried from chamber to chamber as convenience and the conditions of moisture and temperature dictate; the pupæ may even be taken out for a sun-bath, and the whole brood may be rushed to a place of safety when the nest is disturbed.

This method obviously has direct advantages over the more mechanized procedure of the bees. It also has indirect advantages, in that it assures the workers

a much more permanent and intimate contact with their young; and this cannot fail to have reacted upon the evolution of their minds.

If this continued contact with their helpless charges has favoured the growth of many social qualities of their nurses, the intimate contact with their surroundings fixed upon them by their terrestrial habits must have favoured intelligence and pertinacity. As Espinas pointed out half a century ago, in regard to this very point, " on the earth there is not a contact that does not yield precise information." We may add that the obstacles to be constantly overcome (think what a formidable jungle is the grass to an ant dragging its prey, what an Amazon is every streamlet!) must provoke the development of perseverance in ingenuity. Further, " to employ matter is easier for a terrestrial than an aerial animal. The latter, when it is necessary to build, must, like the bee, either secrete the substance of its nest, or seek it at a distance, as does the bee when she collects propolis, or the wasp when she gathers material for her paper. The terrestrial animal has its building materials close at hand, and its architecture may be as varied as these materials." Ants, therefore, probably owe their " social and industrial superiority to their habitat."

It may be added that their dietary habits are equally plastic and varied, as we shall see in a later chapter. The bees confine themselves to nectar and pollen; the wasps live mainly upon other insects, with nectar and very rarely pollen as subsidiary foods; the termites are wholly vegetarians and mainly cellulose-eaters; but the ants eat not only insects and other animals alive or dead, but seeds, fungi, nectar, the honey-dew voided by plant-lice, and many substances which they find in the storehouses and kitchen cupboards of man. Some single ant species have been broken through the all-but-universal rule of food specialization among the insects and have become prodigies in their group by being practically omnivorous.

Most ant-nests, as we have said, are usually irregular and subterranean; but in most cases the excavated earth is thrown out above ground in the form of mounds, and these may be large and be tunnelled and chambered like the rest. Sometimes the main nest is above ground, like the familiar mounds of the big wood-ant of Europe, built of twigs and pine-needles, to three or four feet high. In the tropics and sub-tropics, however, a much greater range of constructional method obtains. Some ants make earth-nests high above ground by plastering earth round the branches of trees; others have reverted to the use of carton like the wasps, and suspend their tough papery dwellings from boughs; others inhabit natural cavities in trees or shrubs; and still others build nests of leaves.

Some of the cavity-dwellers live, not in accidental cracks or rotten holes, but in tubes or chambers which exist as part of the normal structure of certain plants. The fact has given rise to long controversy, some maintaining that the existence of these cavities is quite accidental, while others assert that this is a case of mutual advantage, the presence of the ants helping to protect the plant, and the cavities having thus been developed by natural selection to attract and retain the ants. The second supposition is rendered *a priori* probable by the constancy with which certain ants inhabit only certain cavity-producing trees, and also by the elaborateness of some of the cavities. But it cannot be said that proof has yet been obtained of the advantages supposed to accrue to the plant, so that the matter is still in suspense.

Some of the leaf-builders provide us with a very startling piece of behaviour. They employ child labour. Doflein records how he deliberately made a small hole in such a nest. Almost immediately a number of workers ran up on the outside and, beginning where the rent was narrow, pulled its two edges together, holding on to one side with their jaws, to the other

with their feet, and so gradually approximating the edges throughout its length. Meanwhile another gang of workers had swarmed up on the inside. These were carrying larvæ in their jaws. When the outside gang had pulled the edges into position, those on the inside began squeezing their charges with their jaws. On this the larvæ started to secrete abundantly from their salivary glands. The secretion is strongly adhesive, and the workers use it to stick the edges of the tear together, passing the larvæ to and fro from one edge to the other like so many living shuttles. This same method is also used in the normal building of the nest. The differences between human and ant behaviour are beautifully illustrated by these ants. In so far as the ants adapt their weaving movements to the form of the rent, they are exercising a low but definite form of intelligence. But the basis of the whole action, the utilization of the larvæ, is instinctive. The whole structure of the larvæ is hereditarily altered in relation to their use as builders' tools. Not only are their salivary glands much larger than normal, but their saliva is unique in its stickiness. Without these genetic alterations, which the ants are no more able to bring about than we have consciously brought about the presence of hydrochloric acid in our stomachs or the shape of our bones, the actions of the workers would be entirely useless in the building of the nest.

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CHAPTER III

LIFE HISTORY

In all but the few parasitic ants, which will be described later, the method of founding new colonies is essentially similar throughout the group.

Only the males and females are winged, and they leave the nest for the nuptial flight, usually in swarms of many males and many females from each nest. Any country dweller knows how sometimes the air will be filled for miles with the flying sexual forms of some common kind of ant. Usually these mass exoduses from the subterranean nest-chambers to the free air occur on still, sultry days; and there seems no doubt that particular weather conditions stimulate the males and queens to fly out, thus insuring that many nests shall discharge their reproductive units at the same time, and so promote cross-fertilization between nests.

Neither the short-lived males nor the long-lived queens use their wings save on this one occasion. Fertilization takes place in the air, and the queen, the hundreds of thousands of spermatozoa needed for the rest of her career now safely stored in the little bag, with the tight purse-strings of muscle round its neck, which opens out of her genital tract, descends to earth. There she casts her wings and either digs a little chamber in the soil or finds one ready made under stone or bark. This done, she closes the door of the cell and becomes a voluntary prisoner. Strange to say, the eggs in her ovaries are unripe and minute at the moment of her flight—perhaps in order to save weight and make flight easier—and must now take weeks or even months to ripen. What is more, these weeks or months must be spent without food.

It is the same problem which confronts the

migrating salmon, who does not feed in fresh water on his journey to the spawning-grounds; and it is solved in a somewhat similar but neater way. Large muscles are, of course, required for flying. The shedding of the wings influences these muscles in some specific but not understood way, so that they break down and their substance dissolves and is gradually passed into the blood. This, and the stored fat in her abdomen, constitute the queen's internal food-store. Nourished by this, she matures and lays her eggs, and then, when they hatch, feeds the grubs with her saliva. This food is, of course, not very abundant, and as a result the first workers to emerge are always abnormally small. They at once dig their way out, find food, and take charge of the second batch of young.

The rearing of the young is no light task. In the first place, the eggs appear incapable of hatching unless continually licked by the workers; they must also be carried from place to place according to the conditions of temperature and moisture within the nest. Similar treatment is accorded both to larvæ and pupæ, and seems to be necessary for pupal development—in striking contrast to the bees and wasps, where the eggs are never touched by the workers, and the insect never leaves its little cell until it emerges as a perfect imago. The young are entirely fed by the workers, either with cut-up insect-meat, or in all higher forms by liquid regurgitated from the crop. Strange to say, the larvæ void no fæces, and are, indeed, incapable of doing so, since their stomach does not open into their intestine. The communication is only established just before pupation, and then all the accumulated fæces of larval life are extruded as a single large pellet. This is, perhaps, an adaptation for making easier the task of the workers in keeping the nest clean.

The grubs are regularly washed by their nurses, but this licking, though undoubtedly conducive to cleanli-

ness, springs largely—as we shall see later—from greed on the worker's part. The full-grown grubs spin themselves cocoons, and in this guise are often miscalled "ants' eggs." Finally comes emergence to the unchanging adult state. Here ants once more illustrate the general rule that biological progress goes hand in hand with the greater dependence of the young; almost alone among insects, they require help, or at least are helped, out of their prisons. The adult neuters first help by biting holes in the cocoon; but the insect which then appears is still so far from independence as to merit the special name of a *callow*. It is not fully pigmented, and is still enclosed in what looks like a shirt, but is really its final moult. This is pulled off by the nurses. "When we see how gently this is done," says Büchner, "and how the young creature is then washed, brushed, and fed, we are involuntarily reminded of the nursing of human babies."

Lord Avebury made some interesting observations on the delegation of different tasks to different individual workers. This he did by making hourly observations every day for three months on a small artificial nest, in which the workers had been marked so as to be individually recognized. The colony was fed by being given honey at a definite spot outside the nest. The observations were made during the winter, when not much food is required. For over two months the honey was visited—with a few casual exceptions—by three workers only, which thus acted as sole foragers and transport workers and fed the rest of the colony by regurgitation. At the end of this time he imprisoned one of the three, and on the same evening another ant came out to the food. This new forager continued regularly at its task until after two days she also was imprisoned. Two days later a new forager appeared, joined a few days later by another. In another nest the same thing happened; but here

none of the original foragers were imprisoned, and accordingly continued without change for the three months of the experiment.

How this division of labour is determined is not clear. The beautiful studies of von Frisch on bees, based on the same methods of individual marking, patient observation, and experimentation employed by Lord Avebury, have revolutionized our ideas of bee life. It is certain that an equally rich harvest of knowledge and interest awaits anyone—for the work can be carried out by an amateur just as well as by a professional biologist—who is willing to devote himself to a full study of marked ants, and thus to record the history of a single colony from the start.

It may take several years before a colony is adult; and, even when the swarms of new males and females are discharged, the old colony will continue. For one thing, the old queen may live ten years or more—seventeen-year-olds have been recorded—and will continue—still by means of her single original store of spermatozoa—to produce fertilized eggs until her death. Then, too, in many ants, some of the daughter queens regularly return to the nest after being fecundated, and, since the queen ant, unlike the queen bee, is never hostile to other queens of her own species, the nest comes to have a multiplicity of egg-laying queens, and so becomes potentially as immortal as a human nation. If such a colony continues to grow it will reach an inconvenient size, its food-needs outrunning its communications. When this happens new nests may be formed, just as new settlements were formed by the Greek cities, a band of workers with one or more queens leaving the old home to found a new one. Sometimes the new home is not far from the old, and then a federation of colonies is formed, differing from a number of separate colonies in the fact that all the workers are on friendly terms, and may pay visits to other nests within the federation.

When a solitary queen founds a separate colony, on the other hand, the workers of this colony will exhibit hostility to those of all other colonies of the same species, including that which gave birth to their own royal founder. It seems probable that the friendliness or hostility of the workers to other ants of their own species depends on smell, each nest having some subtle "nest-smell" which is caused by each of its inmates. This smell-based friendliness may be extended to ants of other species, and even to other insects. Not only must the mixed colonies of the slave-makers and the parasitic ants (Chapter VII.) obviously be based on this acquired tolerance, but mixed ant-colonies may be artificially built up by human agency. Miss Fielde, following up some work of Forel, gave to one species of ant the pupæ belonging to another species of ant. When the alien workers hatched out they were accepted as part of the colony. Not only this, but they later showed marked hostility to their own blood-sisters who had been left to grow up in their own nest. Smell is thus to the ant what national traditions are to us—the basis of patriotism; and this patriotism, again as with us, can override the ties of blood and force relatives to fight against each other. In both cases the same end is secured—the subordination of the individual unit to the social unit of which he happens to form part: but the means are different.

The mixed colonies which are to be found in Nature always consist of two quite closely related species. This is, in the main, due to the fact that the rearing of the young is a complex and delicately adjusted process, so that the needs of the larvæ of one kind of ant could scarcely be met by the instincts of the workers of some very different species. When, however, this difficulty is eliminated, as in Miss Fielde's experiments, by inserting full-grown larvæ into a strange nest, it is observed that smell covers a multitude of differences, for she could thus found

compound nests even with two species of widely separated sub-families. The nest-smell doubtless also envelops in its protective mantle most of the many ant-guests, other kinds of insects which live dependently in the abodes of ants; but this we will consider later.

As regards caste and sex, all ant-species possess at least one sterile caste, the workers, in addition to fertile males and females. Anatomy reveals that the worker is a sterilized or neuter female, in whom may be distinguished rudimentary ovaries and oviducts. It seems certain that the difference between female—whether fertile queen or sterile worker—and male is determined, as in bees and wasps, by fertilization or the lack of it. Fertilized eggs produce females, unfertilized eggs produce males; and the control of sex-determination is exercised by means of the tight sphincter of muscle which in the queen's body surrounds the orifice of her purseful of sperms. If this is opened as an egg passes over the aperture, one or a few sperms pass out, and fertilization occurs; if it is kept shut, the egg remains unfertilized and male-producing. We know very little of what influences the queen ant to open or close this destiny-determining circlet of muscle. The differences between neuter and queen appear, again as in most other social insects, to be determined by differences in the quality of food given to the young larvæ, but here once more we know more of detail in bees than in ants. What causes the difference between winged and wingless queens or males, when both forms exist, is not yet known.

The fact that the differences between male and female are determined by heredity, those between queen and neuter by subsequent treatment, is shown by a study of the occasional mosaic monstrosities which occur when one-half or smaller area of the body is of one type, the rest of another type. Now, combinations are known of male part with queen part, of male with

worker, and of male with soldier; but never of queen with either worker or soldier. All such monsters (called *gynandromorphs*) are to be explained through some abnormality of fertilization, presumably through the sperm entering only after the egg has begun to divide, and uniting with the nucleus of one only of the two or more cells produced.

Ants which partake of the nature of both queens and neuters do occur; these, however, the so-called pseudogynes, are never mosaics, but intermediate in every part. They seem to be the result of an alteration of diet in the middle of the grub's development. These pseudogynes, and also occasionally true workers, may lay eggs; but, as the animals have never been fecundated, the eggs can only produce males.

CHAPTER IV

FOOD-ECONOMICS

The members of a human civilized community are tied together by economic bonds. Nobody but the cultivators of the soil can feed themselves by their own labour, and even they tend to specialize on one product, acquiring the rest of what they need by way of exchange. The agricultural population of Java, for instance, is so dense that it can only be kept alive by the import of rice, which is paid for out of the surplus of the exports of the more valuable coffee, rubber, and other vegetables which they cultivate.

With us, of course, there is a universal medium of exchange in the shape of money, and by the use of such a medium we raise our system of mutual ex-

change of services to a far greater level of flexibility than was possible by means of payment in kind or direct barter. The ants in an ant-colony are equally tied into a single economic whole; but the means by which this is accomplished are as unlike and, indeed, alien to those employed by man as is nest-smell to our methods of securing patriotism and the social subordination of the individual.

In the first place, the whole of the colony have, for practical purposes, but a single stomach. This arrangement occurs in such creatures as colonial polyps; but in them it is ensured by direct and permanent communication, the digestive cavities of each individual opening into a common communicating tube in the stalk. The ants have perforce had to adopt a less simple method. The food, after it has been reduced to a liquid soup, is passed down the narrow gullet, which pierces the nerve-collar in the head and traverses the whole thorax to open into the crop (or, as Forel, for reasons soon to appear, christened it, the "social stomach") in the fore part of the abdomen. The crop opens by a complicated valve into the true stomach, which in turn leads into the small intestine, and so *via* the large rectum to the anus.

When a worker has had a good meal, only a fraction of the partially digested food stored in the crop reaches the stomach and intestines, and is absorbed by the animal itself; most of it is distributed to other members of the colony, who solicit it by protruding their tongues and stroking the fortunate one with rapidly vibrating antennæ. On this, a drop of the food is regurgitated from the crop and passed into the other's mouth. The proof of the pudding is in the regurgitation. If an ant be allowed to gorge itself on syrup stained, say, blue, with an aniline dye, the colour will show bright through her abdomen, and, as she distributes portions of it here and there among her fellow-citizens, and they repeat the process, the

abdomens of almost every individual will become faintly tinged with blue. The collective stomach of the colony has been fed.

The food-interrelations between workers and larvæ are even more remarkable. The larvæ recapitulate a less specialized past in having a simpler gut, without a "social stomach," and in being able to deal with solid as well as liquid food. Many of them have a number of spines and roughened ridges near the base of their jaws. These when rubbed against one another possibly generate shrill sounds which, like a baby's howling, may serve to attract their nurses' attention. The remarkable facts elicited notably by Roubaud and by Wheeler both in ants and wasps show that the grubs, after being fed, secrete some liquid which the workers eagerly devour. In wasps and many ants this liquid is a specially sweetened saliva; but the majority of ants exude a fatty substance through their cuticle. In one sub-family of ants the larvæ are provided with extraordinary appendages which secrete a substance of this kind in more concentrated form, and are, one presumes, easier to suck.

To quote Wheeler's words: "Although these various substances are produced in very small quantities, they are of such qualities that they are eagerly sought by the adult ants. This explains much of the behaviour which has been attributed to maternal affection on the part of the queen and the workers, such as the continual licking or fondling of the larvæ, the ferocity with which they are defended, and the solicitude with which they are removed when the nest is disturbed. In other words, a decidedly egoistic appetite and not a purely altruistic anxiety for the welfare of the young constitutes the potent 'drive' that initiates and sustains the intimate relations of the adult ants to the larvæ, just as the mutual regurgitation of food initiates and sustains similar relations among the adult workers themselves." This payment

by the larvæ for services rendered, Wheeler has christened *trophallaxis,* or exchange of food-stuffs. Thus, if the ants' patriotism is based on smell, their economic and social stability is founded on taste. The two cementing principles are rather different, since the common smell merely envelops the colony and binds it together, whereas in trophallaxis there is a real economic exchange and a true bargain struck, the larvæ presenting the adults with coveted substances, unobtainable elsewhere, in return for attendance and plenty of plain food.

Since the subject is of such vital importance, we may here diverge a moment to look at trophallaxis among the wasps, where it exhibits certain simpler and more clear cut features. The substance offered by wasp grubs to their adults is always the secretion of the salivary glands, which have apparently lost all their digestive functions and now secrete an abundant sugary liquid entirely devoted to rewarding their nurses.

Roubaud describes the act of trophallaxis thus: "As soon as a nurse wasp has distributed her food-pellet, she advances with rapidly vibrating wings to the opening of each cell containing a larva in order to imbibe the saliva that flows abundantly from its mouth. . . . The wing vibrations of the nurse serve as a signal to the larva which, in order to receive the food, protrudes its head from the cell. This simple movement is often accompanied by an immediate flow of saliva. But if the secretion does not appear, the wasp seizes the larva's head in her jaws, draws it towards her, and then suddenly jams it back into the cell, into which she then thrusts her head. These movements involve the stimulation of the larva's mouth, and force it to secrete its salivary liquid."

The nurses may return three or four times to obtain this secretion after they have fed their charges but once. What is more, the larvæ are sometimes ex-

ploited, and, by means of the curious handling just described (which appears to be instinctive, in origin at least, on the part of the adults), made to secrete saliva without any compensatory gift of food. This, which amounts in the wasp's economic system to thieving, is practised almost entirely by workers which have just emerged, by the queen, and by males. It is interesting to find that this secretion can be artificially induced, either by touching the larvæ on the borders of their mouths, or by simulating the effect of the nurses' vibrated wings by whistling near by. " It is only necessary to whistle loudly or emit shrill sounds near a nest of Belonogaster to see all the larvæ protrude their heads at the orifice of their cells."

J. B. S. Haldane has pointed out a further biological meaning in the wasps' trophallaxis. Most of the food actually in the blood-stream of a mammal is utilized as fuel, in the form of sugar. The nitrogen-containing amino-acids derived from meat and other proteins are employed for tissue repair, but only quite small quantities are needed for this, the remainder being broken down into sugar further utilizable as fuel and waste nitrogenous substances like urea. The growing puppy or human child, on the other hand, utilizes a much greater amount of its nitrogenous food, since it has to build tissue as well as repair it. In these respects, insects are like mammals, but more so, since the cold-blooded, sluggish grub requires relatively less fuel. Thus trophallaxis as practised by wasps is not only a system of services and rewards—it also ensures a more economical utilization of the food. As Haldane says, " When a worker comes to feed a grub . . . the grub thanks it by secreting a drop of fluid containing sugar for which it has no use, but which is valuable fuel for an active insect " (and one, we may add, which is no longer growing).

The bees, curiously enough, appear to lack all trophallaxis between grub and adult, nor is there any

transference of food from one worker to another. The first point may be accounted for by the facts mentioned by Haldane. The food of bees consists mainly of the sugar-containing nectar, transformed into honey during its sojourn in their crop, and the pollen, or bee bread, rich in protein. The adult bees require no extra carbohydrate, since they obtain it directly in their ordinary food; the grub can have its nitrogenous and non-nitrogenous rations exactly dosed. The lack of mutual feeding by the adults can be equally easily accounted for: the bees have produced an artificial substitute for the "communal stomach" of the ant colony, in the shape of their cells of pollen and honey. The workers regurgitate their gathered stores into these instead of into other workers' mouths; and, since some of them are always left open, home-staying bees can always draw upon them when hungry.

Finally, the Termites have developed very extraordinary systems of communal food exchange, which will be discussed in a later chapter.

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CHAPTER V

ANT SENSES

The senses of ants are of considerable interest. Sight can never be very acute, as the compound eyes have few and widely diverging facets. The simple eyes or ocelli, present in almost all forms, can only serve for extremely near vision, or perhaps merely for distinguishing light from darkness. The Driver ants, for all their ferocity and active migrations, are wholly blind. It is of some interest that some ants, at least, are sensitive to a certain range of ultra-violet light unperceived by us.

In ants the only sense organs of any delicacy of discrimination are the antennæ. These mobile organs explore the environment with a combination of smell and of touch in a way which we, with our organs of smell fixed within our skulls, can scarcely imagine. Smells for us are without form and void. But ants can undoubtedly distinguish the shape of all such smells as are being given off by definite bodies of small size, and they must have a composite notion of such a body in terms of colour, flat shape, and shading derived from sight, and solidity derived from touch. In the battles between different colonies of the same species of ant, friends cannot be distinguished from foes by distinctive markings or uniform, nor are there any battle-cries. It appears that a touch of the antennæ at once decides the point.

An obvious problem of ant biology is to know how they find their way back to the nest after long expeditions into the surrounding country. Once well-marked trails have been established, the track itself and the smell adhering to it simplify matters a good deal. But what of solitary workers exploring off the beaten track, and their power not only of returning to the nest, but also of bringing back a band of other workers to any source of food they may have discovered?

As a matter of fact, most species of ant seem to employ three or four different methods in finding their way. To a slight extent they utilize what to us is the most important method—that of orientating themselves with regard to objects in the landscape. Wherever there exists a trail over which they or other ants have gone, they rely largely upon smell. Smell, however, cannot very well tell them much about direction. Although Bethe put forward an elaborate theory in which he supposed that an ant, by means of its power of detecting the shape of smells, could distinguish in which direction ant footprints were headed, he had to make the further supposition that the ants

travelling out from the nest imparted a somewhat different smell to their traces from those coming back. Recent workers, however, following up a clue left by Lord Avebury, have been able to show that this is not so, and that the ants are guided in their direction by the direction of the light falling upon them. If, for instance, a solitary questing ant is imprisoned under a box for three hours, and the box then taken off, it sets off in a direction which deviates from its original line by the same angle through which the sun has travelled during its imprisonment—in this case 45 degrees. This it will do whether it had been travelling directly towards or away from the sun, or at an angle to its light. In artificial nests the ants can be completely tricked by moving the source of light. Apparently, on days which are overcast, the ants can still orient themselves approximately in relation to the part of the sky most strongly illuminated; but more experiments are needed on this point.

Finally, the ants must have some sort of sense of distance, for when an ant has been tricked, by being kept prisoner for a time, into following a false direction on its homeward way, it stops its straight, unhesitating march when it has travelled a distance, which, had it been moving straight homewards, would have brought it to the near neighbourhood of the nest, and begins to quest about in every direction. Apparently this faculty depends on some utilization of the kinæsthetic or muscular sense, the number of leg-movements being more or less accurately registered. It is certain that a similar mechanism is at the basis of the power of rats and other animals to learn a maze. Whatever the precise machinery at work, there is no doubt that many animals do possess some such automatically registering pedometer as part of their equipment.

Many are the stories of ant intelligence. Most of them, however, smack much rather of trial and error,

or of adapting instinct slightly to unusual circumstances, than to intelligence properly so called.

Some ants are undoubtedly very stupid, judged by our standards. Lord Avebury found that the little ants which he kept in captivity could not learn to build up earth into a pile an eighth of an inch in height in order to get at some honey which they could smell and see just out of reach, nor to perform a number of equally simple mechanical acts which would have secured them food or access to their larvæ.

On the other hand, there are trustworthy accounts of Driver ants bridging streams by each worker seizing a twig and then forming a living chain-bridge across the water, over which the rest of the army can cross; and Bates himself records how the path of some South American ants lay across a tram-line, and how, after a large number had been squashed by the tram, they made tunnels under the rails. When Bates stopped up these tunnels the workers refused to cross the rails, but waited until new tunnels were made. Cardinal Fleury communicated to the great Réaumur his observations of how ants surmounted a girdle of bird-lime smeared round the trunk of a tree by laying a road of earth and small stones across it; and the fact has been corroborated in recent years, one observer stating that he had seen ants, trapped on a tree by a band of tar, bridge the obstacle with their own ant-cows! Others in similar predicament have been known to reascend the tree and drop from the branches, although Lord Avebury's ants (perhaps because they belonged to a species with very poor sight and less roving habits) refused to let themselves drop through half an inch.

Some of the building activities of ants, too, display definite intelligence in the sense of the adapting of means to ends, but there, too, instinctive foundation always remains and is larger than the superstructure of intelligence. The enormous gulf between the intelli-

gence of ants and our own is most readily realized by reflecting that no ant receives any education. The larvæ are mere machines for growing up as quickly as possible, with the most rudimentary sense-organs and no limbs; even if they were taught, which they are not, their capacity for profiting from the instruction could not very well transcend that of an earthworm.

The pupæ are shut away from the world in their cocoons, busy with the task of transforming their whole organization from that of helpless grub to winged six-legged creature. Finally the adults, once emerged, can set about performing all their complex tasks without the least instruction, as is shown both by observation of young nests and by experiment. They find the food proper to the species, they build the right kind of nests, they tend the young in one particular way. They may improve as the result of practice, or may have new habits thrust upon them by necessity and experience; but there appears to be no way in which tradition can be communicated from older to younger workers, and certainly no way in which it can be transmitted to a new nest. In respect of education and tradition, even the highest of social insects is below the level of a mammal like the dog.

All ants are extremely cleanly animals. Not only, however, are they cleanly with regard to their own persons, but their social nature prompts them to mutual assistance in matters of the toilet. We may take McCook's account of the operation in the fungus-gardener Atta: "We take a couple; the cleaner has begun at the face, which is licked thoroughly, even the mandibles being cared for. . . . From the face the cleaner passes to the thorax, thence to the haunch, and so along the first leg, along the second and third in the same manner, around to the abdomen, and thence up the other side of the ant to the head. . . . The attitude of the cleansed all this while is one of intense satisfaction, quite resembling that of a family

dog when one is scratching the back of his neck. The insect stretches out her limbs, and as her friend takes them successively into hand, yields them limp and supple to her manipulation; she rolls gently over upon her side . . . and with all her limbs relaxed presents a perfect picture of muscular surrender. . . . I have seen an ant kneel down before another and thrust forward the head, drooping, quite under the face, and lie there motionless, thus expressing . . . her desire to be cleansed. I at once understood the gesture, and so did the supplicated ant, for she immediately went to work."

Ants, like other higher insects at least, require sleep. The exposition of sleep may come on at any time of day, and its duration, in those species where it has been timed, averages some three hours. They may choose a depression in the soil as bed, and there lay themselves down, with legs drawn close to the body. When asleep, they may be stroked or tickled without awaking, though a sharper tap rouses them at once. When waking naturally, they behave in a way startlingly like that of mammals or our proud human selves. The head and then the six legs are stretched to their fullest extent, and then often shaken; the jaws are strained open in a way remarkably reminiscent of a yawn. One interesting observation made by McCook on an American harvesting ant with great difference in size between the workers and soldiers, was that the soldiers sleep longer, and also more heavily, being much less easily awakened.

Some observations indicate that ants have reached that high state of mental development at which play appears. The sport generally consists in mock fight between the workers of a single colony, the ants behaving just like dogs when they play at fighting. They may also pursue each other, again like puppies, or like children playing tag.

This brief account of some of the general habits

of ants may fittingly conclude with a reference to the way in which their bodies are disposed of by the community after death. Some of the older naturalists gave the most circumstantial accounts of regular ant funerals, with corpses borne by workers two and two in procession, and finally interred in separate graves. It appears that imagination had here a little outrun fact; none the less, the fact is interesting enough. Most ants are extremely anxious to dispose of any corpses, and if kept in a small artificial nest will wander round with their burdens, often for days, searching for a suitable spot. In nature, the usual cemetery is simply the communal refuse-heap, so that it is probable that the corpses are merely regarded as so much refuse, and the apparent solemn burial of the dead turns out to be only a special case of the ants' passion, doubtless implanted by natural selection on account of its utility to the colony, for keeping the nest tidy. It has, however, been asserted that the slave-making *Formica sanguinea* has separate places of disposal for the corpses of its own species and that of its slaves.

CHAPTER VI

WAYS OF LIFE AMONG ANTS

Ants are essentially terrestrial creatures, though a few have secondarily taken to tree-life. Though of world-wide distribution, they are pre-eminently inhabitants of dry or desert regions. In structure, they bear witness to definite relationship with the Scolioids, a group of solitary wasps, and there can be little doubt that

they have originated from a ground-nesting wasp of this type which took to social life with loss of wings in the workers, but not in the sexual forms. Their abundance in arid lands suggests that this development first took place in one of the long arid periods of the northern hemisphere, presumably in the Trias or Lias of the Secondary epoch.

At the beginning, all the workers were doubtless alike, and not markedly dissimilar from the queens. But terrestrial life and social specialization gradually rendered the ant neuter more unlike the queen than in any wasp or bee. Meanwhile, the average size of the colony doubtless increased.

There exist to-day seven sub-families of ants. Of these the Ponerines are undoubtedly the most primitive. In them and two other rather primitive sub-families the neuter is still almost as big as the queen, and there is never more than one kind of worker. Among the remaining four the neuters are often (though by no means always) divided into sub-castes, which differ not only in size but also in form, the larger always having relatively enormous heads and jaws. These big fellows are the soldiers, and usually live up to their name by acting as defenders of the colony, though in some species they help the larder by crushing up hard seeds or insects, which would defeat the weaker jaws and smaller size of the ordinary worker. Primitively it appears that a whole graded series of neuter types is produced. Later the middle forms (and sometimes also some of the smallest) may be eliminated, leaving only sharply defined worker and soldier sub-castes; or all the large and middle-sized types may disappear, leaving only the tiniest workers to carry on the business of the nest.

In addition, both queen and male castes may become sub-divided, wingless as well as winged forms being produced. And here again, in further evolution,

the original winged type may be suppressed, leaving only the wingless as reproducer-caste.

The two highest sub-families are the Myrmicines and the Formicines. Scarcely any other ants have succeeded in pushing out of the tropics or sub-tropics, but these groups are found abundantly over the north temperate region.

In the primitive sub-families the diet consists exclusively of other animals, mostly insects; thus ants as well as man began as hunters. One of these groups, the Dorylines, better known as Driver or Legionary ants, have raised hunting to a high pitch. They have no fixed nest, but range the country in huge bands, often of several hundred thousand workers, all blind, and all ferocious, devouring any living creature which does not take to flight, and many are the nests of other ants which fall a prey to them.

Among the higher forms many genera have left the hunting for the pastoral life, living directly or indirectly on the sap of plants. In some few cases this "honey-dew" is secreted by the plant in special nectaries on stalk or leaf, its function apparently being to attract ants, which then serve instead of thorns or bitter juice to help keep away devourers. But in most cases the ants take advantage of the much more abundant supply afforded by the various little sap-sucking insects—aphids, scale-insects, leaf-hoppers, and the rest. These wasteful creatures only use a fraction of the sugary solution which, with their sharp proboscis, they are imbibing all day long; the remainder exudes at their anus. The ants, however, always the exemplars of frugality, have not tolerated this waste. They either lick up the excreted "honey-dew" from the surface of the leaves, or "milk" the animals by stroking them with their antennæ. Finally, some species actually domesticate these ant-cows; and others store the honey-dew against the dry season—in an extraordinary way of which an account will be given later.

Then in some Myrmicines, the pastoral stage has given place to the agricultural. A halfway house is reached by the so-called harvesters, which collect the seeds of grasses and store them in regular granaries, although, contrary to early belief, they never sow seeds for a new crop, and so do not fully merit the name of agriculturists. But some other genera of the same sub-family practise a real horticulture, growing fungi for food, and attending to the growth and reproduction of their vegetable plots as assiduously as any human gardener.

Finally, as a strange overshooting of the mark, a specialization which eventually leads downhill, there are the thieving, slave-making, and parasitic ants. There exist ants which are occasional brigands; others which are persistent thieves, and some which are servile parasites. In both Formicines and Myrmicines, the subtler form of parasitism which starts as slave-making has been evolved. Some are temporary slave-makers, others must live with slaves all their lives, and still others have completely lost their worker caste, the queens and males living as mere parasites on their slaves.

There is no reason whatever to suppose that the ant-type will not continue to flourish through future geological periods as admirably as it has done in the past. As a type, it most efficiently fills a definite niche in terrestrial life. A few species will doubtless be exterminated by man, some deliberately, others as the unforeseen result of agriculture and other human activities; but the type as a whole will be protected by its small size, subterranean habits, and adaptability. New species and new modes of life will doubtless come into existence, but the type itself will persist essentially unchanged, as a witness to the biological success of social life utilizing the efficient machinery of insect structure and held together by firm and elaborate instincts.

After this brief general sketch of ant evolution, we

may turn to some actual pictures of ant-life, as led by different species of this strangest of all earth's little peoples.

Market Gardening Ants

Let us look first at Atta, chief among ant-gardeners. In the woods of Southern Texas there may occasionally be seen processions of ants, following well-worn trails often a hundred yards or more in length. Those going in one direction are empty-jawed, and walk on one side of the road; those going the other way keep to the other side and carry a piece of green leaf. The piece of leaf is often so large as to hide the animal that carries it, and has led to these creatures being called parasol ants. The leafless workers are on their way up trees; there they cut out their green "parasols" with their jaws; and thence carry them back to the nest, or let them fall one after another to the ground to be picked up by another gang there. The nest may be enormous, a veritable subterranean city, the débris of its excavations piled into mounds ten or twenty feet across. The mound of the common Brazilian parasol ant, *Atta sexdens,* may run to 265 cubic metres of earth, weighing many hundred tons, and may shelter over half a million individuals.

The neuters of Atta cover a great range of size, from the huge-headed soldiers down through large and medium and small workers to the tiny *minimæ*. The soldiers defend the nest, and police the bands of medium and large workers who make it their business to clip the leaves.

In the nest the leaf pieces are cut into smaller bits and built up into beds on the floor of the large subterranean chambers which other workers have previously excavated. These beds are then handed over to the smallest workers, who work only underground, though they are said to come up occasionally to play

about in the light and air. On the beds of decaying leaf a white network of fungus grows: this is tended by the smallest workers, who treat it by some unknown method which makes the threads produce clusters of small spherical swellings. These miniature white cabbage-heads are bitten off and used by the ants as the staple food both of themselves and their young. The ants seem very careful about the proper ventilation of the gardens, and Bates describes them as opening or closing some of the numerous holes leading to the surface from the fungus-chambers, according to the conditions of moisture and temperature. They are also careful not to bring in pieces of leaf if they are too wet, but leave them near the entrance to dry. Grass is apparently unsuitable for fungus-beds. In spite of this, ants are occasionally seen carrying bits of grass into the nest; but these are always thrown out again after a time.

Every species of Atta grows a different kind of fungus, and, what is more, weeds out any other which may start to grow in the nest. The fungus-heads are artificial productions of the ants' gardening just as definitely as are good white asparagus stalks the product of the treatment the plant receives from man: they do not appear when the fungus is grown in the laboratory. Indeed, they are much more modified than asparagus, for the fungus-threads are really the mycelium, or "spawn," of a regular mushroom. So long as the ants' cultivation continues, the fruiting mushroom structure never appears, but in abandoned nests they are sometimes found pushing up. Several distinct genera of fungus have thus been domesticated by the Atticine ants, including one which is not related to the mushrooms at all, but is more like yeast.

It is probable that the Atta workers manure the gardens with their own excrement. Certainly some related forms use the dung of caterpillars and other insects as the substratum for the fungus, in place of

leaves. Others suspend the fungus-beds from the ceiling.

The transference of the precious fungus from colony to colony is effected by the queens. All ants possess in the forepart of their mouths a pouch, the so-called infra-buccal pocket. Into this, in the ordinary ant, are swept first the more solid food-particles after they have been masticated by the jaws, and also, strangely enough, the combings and scrapings of the ants' toilet. These latter are combed off her legs and antennæ by means of a pair of opposable combs on the fore-leg, and licked off the rest of her body by the cleanly creature's tongue. The pellet in the pouch is moistened with saliva, which dissolves out any available food, and when it has reached a certain size it is thrown out. No adult ant thus swallows anything but liquids.

The pocket is utilized by the parasol ants for the inoculation of new nests with fungus. The virgin queen, before leaving the nest on her nuptial flight, takes a hearty meal—of fungus, of course. Threads of the mycelium, together apparently with some of the leaf-soil, are packed into her infra-buccal pocket. After she has mated, cast her wings, and constructed a small underground room as beginning of the future nest, she spits out the pellet on to the floor. The fungus, of course, begins to grow, and the queen tends it with the greatest care, manuring it with her fæces, and even breaking up some of her own eggs to furnish more "soil." She uses the garden as a nest for other eggs; the larvæ from these hatch out, feed on the fungus, and turn into workers. These, untaught, break out of the chamber, raid trees for leaves, and take the charge of the garden off the queen's shoulders. Thus an extremely slight modification of an old-established habit suffices to ensure what at first sight seems to us no simple task—the transmission of the fungus-vegetable to new nests.

It is interesting to find that the cast pellets of most sorts of ants almost always contain fungus-spores. What is more, most ants have a regular refuse-heap in or near the nest, and many species make a practice of voiding their pellets here, just as man and several mammals, like the rhinoceros, prefer to defæcate in definite spots. This refuse-heap affords favourable conditions for the germination of fungi, and in point of fact in some species of Crematogaster not only does an abundant crop of fungus-threads grow on the refuse-heaps, but the ants actually use this as part of their diet. And from an accidental state of affairs such as this it is not a very large step to that found in the true fungus-growers. Thus even such a surprising activity as deliberate vegetable-gardening can have had a comparatively simple and intelligible evolution.

Harvesting Ants.

It was *Messor barbarus,* one of the harvesting ants to which Solomon referred when he wrote his celebrated advice to the sluggard (Prov. vi. 6). It was for many years believed that these creatures not only stored grain but actually sowed it in definite fields in order to raise a new crop. In view of what has occurred with the fungus-growers, this would be quite possible (save that it is more difficult to think of the practice arising when months instead of days or hours must elapse before the new crop appears); it merely happens not to be true. These ants often clear a considerable area round their nests; and on this bare area grasses may sometimes be found sprouting. However, this is not due to any deliberate sowing by the ants, but only to the germination of accidentally dropped seeds.

The harvesters are all inhabitants of desert or semi-desert regions. Not only is insect-food scarce, but

there are long periods of drought in which both active plant and animal life is almost absent. Thus the ants find in seeds a welcome addition to their diet, and also a food which can be stored against a dry season. When they can find insects, they still will eat them readily enough. Several of these ants have neuters ranging from small workers up to huge-headed "soldiers." These latter, although they are precisely similar in general structure to ordinary soldiers, have taken upon themselves a new and different function. The larger and harder seeds are broken up by them with their enormous mandibles, and so made available to the rest of the colony.

In some cases—for instance, the Myrmicine harvester (*Pheidole instabilis*) from Texas—there is a complete and continuous gradation between the largest soldier and the smallest worker, as in Atta and some of the Driver ants. When the whole series is examined it is seen that the differences between the various forms are differences of proportion: the larger the neuter, the relatively larger head-organs does it possess. What is more, whenever in such forms the weights of head and body are taken, it is found that they obey a simple mathematical relationship—head-weight is a function of rest-of-body weight raised to a power; and this would imply that head and body grow at different rates, but rates which always bear a constant ratio to one another, like two sums of money accumulating at different rates of compound interest.

These facts give us a probable clue to the origin of the sub-castes among ant neuters. There is always some variation in the adult size of insects, due to the quantity of food available to the larvæ. The social insects are no exception to the rule; one of the most striking examples is given by the Humble-bee, in which the first-hatched members of a new nest, owing to the overworked queen not being able to provide a great deal of food, are always smaller than their

mother—sometimes scarcely larger than house-flies—although they are not neuter. The neuters of all ants vary in the same way, the range of size being much greater in some species than in others. In many cases the difference is one of size alone, the proportions of parts remaining the same. Even here the variation may be turned to advantage, very small workers being suited for delicate work in the nest, very large ones for heavy jobs in transport or construction; and, if advantageous, the condition would readily be brought about through the nurses giving abundant food to some larvæ, very little to others.

But growth of all parts of the body at the same rate is really only a special case; in reality, different parts usually grow at slightly different rates. The jaws of ants are their main tools and weapons both. Thus the advantages of size-variation would obviously be intensified if the large individuals had also more powerful jaws—and therefore, because of the muscles required, larger heads—and this would be insured if in the pupa the rate of growth of the rudiments of the adult head was greater than that of the rest of the body. Not much difference is necessary; the head's growth-rate need never be twice as great as the body's to produce soldiers which are almost monstrous.

Thus the whole gamut from super-soldier to *minima* workers one-fiftieth their bulk could be produced by a combination of two well-known principles—variation in imago-size dependent upon the amount of food received by the larva, and the differential growth-rate of one region of the body. The growth-rates are given by heredity; once they are established, all that is needful is that the worker-nurses should vary the food-supply of the grubs. The view that this has actually been the course of events in ants is supported by the fact that whenever new nests, of species with polymorphic neuters, are founded by single queens, the first brood consists only of small workers and never contains

soldiers; for the same reason, one presumes, that the first brood of humble-bees are small—because the queen has not time nor energy to feed them up.

In the genus Pheidole, some species, like *instabilis*, exhibit the complete gradation we have just studied; but the great majority possess nothing but soldiers and tiny workers. This must be due to a further specialization of the nurses' behaviour—they either feed their charges to the fullest extent, or keep them on a definite scale of reduced rations. The result is a sharpening of the division of labour—a specialization perfectly analogous to that between the different tissues of the body.

Ant-Cows.

It was Linnæus who first christened plant-lice the ants' cows; and the phrase is perfectly legitimate. The domestication of plant-lice has reached such a pitch among certain ants that the masters—or, rather, mistresses—collect the "cows'" eggs in autumn, keep them through the winter in their own nests, tending them like their own, and in the spring, when they begin to hatch, plant them out in their pastures, distributing them over the roots, leaves, or stems of neighbouring plants. For instance, *Lasius americanus*, one of the commonest ants of the United States, distributes plant-lice far and wide over the roots of Indian corn; while in the European *Lasius flavus* Lubbock found them planting out eggs on to daisy-plants, and others take their charges high up on to trees. Other ants keep their dairy beasts browsing on roots in specially constructed rooms underground, or even build sheds or barns over them as they suck the juices of leaves high up on shrubs or trees. These sheds are sometimes connected by long, covered ways with the nest. Care is usually taken to have the doors too small for the cows to get out, though big enough for the ants.

All such herd-masters practise the "milking" of their insects, stimulating them to defæcate by stroking their bodies with their antennæ. Darwin and others have tried to imitate this by stroking aphids with a hair, but this is of no effect; yet even very young aphids respond at once to the blandishment of the ants' feelers, though, in the absence of this stimulus, they hold up their secretion for long hours.

When the ant-cows are kept permanently underground, as in plant-lice and mealy-bugs tended by *Lasius americanus,* they become snow-white—not, as with our white cows or horses, through positive selection, but through the direct or indirect effect of the lack of light. What is more, their herd-mistresses, never needing to come above ground for their food, are pale yellow in colour, and have become almost blind, with vestigially minute eyes.

As we have seen, this dairying life has grown up naturally enough. It is based on the fact that the sap-sucking insects utilize only a small portion of the sap they pump up from the plant tissues, but void the major part of it. From licking up this sweet liquid, so agreeably made available to the ants—for their own jaws are useless for sap-extraction—to waiting for the actual voiding is only a simple step enough, and the stroking of the "cows" to speed up the appearance of the drop is another. The ants' invention of milking other insects is certainly no greater, as an evolutionary advance, than man's invention of milking other mammals.

Just as man's agriculture, whenever it becomes at all systematic, is extremely deleterious to most other organisms, what with the felling of forests, the draining of marshes, the killing of beasts of prey, the banishment of so many birds which need cover or solitude; so the dairying propensities of the ants constitute one of the most harmful of all their activities. So numerous are the species engaged in the protection

and often in the active dissemination of sap-sucking insects that a heavy toll is laid on plants, and man's efforts to keep his crops, flowers, and fruit-trees clean of these vitality-sapping pests are, in large part, rendered vain.

Honey-pot Ants.

Just as the harvester ants must store the seeds on which they live to tide over the dry season, so, too, the honey-dew eaters of arid regions must find some method of storage. Liquid food, however, is not easy to keep. The honey-bee has solved the problem; but the honeycomb is the climax of a long and gradual evolution. The ants never adopted this type of storage method, and the sudden invention of a pot or bin with an air-tight lid is not simple when evolution is working mainly by instinct. The honey-ants have arrived at a different solution, which is unexpected to us, but natural enough in insects—they convert some of the workers themselves into storage vessels. These living honey-pots have an enormously distensible crop, and the foraging-workers in the season of plenty feed and feed them by regurgitation until their abdomen becomes swollen to a huge spherical bag, the plates of its skeleton eventually becoming isolated on a great area of tight-stretched elastic skin. The "repletes," as they are called, are quite incapable of walking, and remain suspended by their claws from the roof of special chambers, in which a number of these "animated demijohns" hang side by side for months. In the dry season the ordinary workers stimulate them to regurgitate in the usual way, by stroking their heads, and so the whole colony is kept alive out of their capacious bellies.

This adaptation has been evolved independently in three sub-families of ants, always in desert countries. It is interesting to find that the single genus Pheidole

contains species adapted wholly to harvesting and others wholly to this storing of honey-dew. It is not known whether the repletes are predetermined for their task by the possession of specially distensible crops. More probably the possibility is open to all workers, but only a certain proportion of them have repletion thrust upon them.

The Legionary Ants.

The predatory habit has been carried to its farthest extreme by the Legionary or Driver ants, already mentioned. These dreaded creatures, with their destructive instincts, their nomadic habits, and the vast numbers of their hordes, remind us of the invading hosts of Huns or Tartars in our own history. But here again the fundamental differences between man and insect appear. The most restless of the Mongols was capable of settling down to a stable and civilized life. But the Driver ants are for ever limited to their way of life by the iron hand of heredity. Their nomadism and their ferocity are permanent; their wanderings are barbarous invasions that never end.

Their blindness makes them more uncanny to us; but it is only one more instance of the subordination of sight to smell among ants in general. They usually exhibit great polymorphism among their neuters, the powerful soldiers attacking the largest prey—even horses and cattle are attacked and killed, when tethered—and rendering it available to the others; the small workers are equally ferocious and see to it that smaller creatures do not escape. The males, as usual, are winged; but the queens are permanently wingless, and grow into great egg-laying machines only excelled in bloatedness by queen termites.

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CHAPTER VII

WARFARE AND SLAVERY

Ants are among the very few organisms other than man which go to war. Individual insects or spiders, fish or birds or mammals, fight each other for food or mates or breeding-sites; but this is not war. When a herd of wolves attacks a herd of wild horses, and the prey vigorously defends itself, this is a first approximation to war. But strictly the term should be confined to battles between armies of the same or closely related species. In ants there are all gradations from the pure predatism of such forms as the Legionaries, against which no other ant defends itself, up through stages where the species preyed upon occasionally defends itself vigorously or even takes the offensive, to those of habitual warfare between closely allied species, and, finally, battles between different nests of the same species.

The best-known military activities of ants are those concerned with the raids of the slave-makers on the nests of the related species from which they wish to steal pupæ to be reared as slaves. The general biology of slave-making will be considered later; but the purely military aspects may be treated here.

In more peaceful species solitary workers scout about for food, and, after it is found, their return to the nest is followed by a large exodus of other workers to exploit the provisions. Similarly, the slave-makers' scouts go out in search of suitable nests to attack; and, when they return successful, all the neuters of the nest advance to the attack in a body. The Amazon slave-maker, Polyergus, forms in dense columns when near the objective, apparently searching for the scent. Such columns may be fifteen feet long,

with breadth up to six inches, and the march may last an hour, at an average speed of a yard a minute, or more. The leading ants are apparently sniffing eagerly for the scent of the slave-species. When this is found they dash forward to the attack. Some slave-species fly at once. Others offer violent resistance; but they are usually driven to fleeing with as many larvæ and pupæ as they can save, and to pursuing the Amazons, when they retreat, in the attempt to retrieve some of their booty. The returning column of slave-makers, guided solely by smell, follows the precise route which it took on the outward journey.

Forel has seen a whole army of Amazons lose its way and fail to find its objective; when the way is very long they may, though headed correctly, turn back again, apparently as the result of fatigue. There seems to be no leadership in the human sense, but some ants often appear to be very half-hearted and need to be tapped with the antennæ of more actively inclined animals before they will advance. Halts are often made to let the column close up, and usually again when the van has arrived close to the objective.

The same nest may be attacked day after day until there is nothing left to steal, or the inmates move to a new site. One Amazon colony, watched every day for a month, was seen to send out forty-four raiding expeditions, of which twenty-eight were complete triumphs, nine gained a few pupæ, and seven were total failures.

In one case observed by Forel some of the colony of *Formica fusca* which was attacked defended the nest with great vigour, while others succeeded in carrying the great majority of the brood out of danger, upon which the Amazons gave up the attack and began retreating. The *fusca,* however, violently excited, poured after and pursued them, and were so successful in harassing them that the enemy released the slave-young they had captured, and got away by utilizing

their superior speed. Such a defeat is exceptional. In this case it seems to have resulted from the front of the attacking column having come within sight of the defenders before they expected, and to the pause which then ensued while the rear was brought up being utilized by the *fusca* to man the nest thoroughly for defence.

Forel has also observed the attacked ants follow the slave-makers to their own nest, and launch themselves in hundreds in a vain assault upon it. The hostility of slave-making and slave-species is but a special case of normal prey defending itself. But different species of slave-makers are violently hostile to each other, and when they meet may wage battles as bloody as those against the slave-species. Finally comes the warfare in which the ants rival man, in which all the combatants are members of the same species. The Harvester ants seem to be the chief of such fighters, the accumulation of portable possessions leading, as with us, to cupidity and war. Such wars are fully as savage as those between the slave-makers and their victims, and may be very prolonged. One campaign between two neighbouring nests, described by Moggridge, lasted forty-six days; another, observed by McCook, which took place in Penn Square, in Philadelphia, lasted nearly three weeks.

One of the commonest causes of war is the building of a new nest too close to an old-established one, the ants in them displaying a territorial instinct very like that of many birds; on other occasions, however, scarcity of food may lead to hostilities between two nests previously at peace with each other.

The fact that two species of ants constantly nest in close proximity is the first step towards the form of parasitism which has had the name of slave-making applied to it, for, as Wheeler remarks, " different ant colonies, even of the same species, are so hostile that their mere existence in such contiguity implies that

one of the species is to some extent exploiting the other."

Some small ants live like brigands in dwellings close to the pathways of other ants, and snatch food from the returning workers, just as the skua compels the gull to disgorge its booty. The reason they are not attacked by their victims is not clear, but, as with the gulls and skuas, may lie in a difference in the disposition of the two species. Others, always of minute size, are permanent thieves. They make nests in the very walls of large ant or termite nests, and connect the galleries of the two dwellings by passages large enough for their own use, but far too small for their large neighbours to pay a return visit. An extreme adaptation to such a life is shown by Carebara, which steals from termites. The workers, in accordance with their mode of life, are among the smallest of all ants, while the males and queens are of more or less normal ant-size, and weigh over a thousand times as much. When the queen flies out on her marriage flight she takes a number of the little workers with her, clinging on by their jaws to the hairs of her legs. It has been plausibly suggested that this is an adaptation to the huge disproportion in size between the queen and the worker, since the queen could no more feed her pigmy offspring by regurgitation than could the ladies of Brobdignag have successfully given the breast to a normal-sized human baby, and needs neuter nurses from the first. As an example of the blind nature of ant behaviour, it may be mentioned that workers, at the moment of the nuptial exodus, attach themselves indiscriminately to males as well as to queens, in spite of the fact that all which happen to take the male conveyances must die without fulfilling any useful function.

Occasionally weak, small ants live near the nests of large ones, merely, it would seem, to enjoy some protection from their powerful neighbours' proximity; and, at its highest, this relationship passes the low barrier

which separates one-sided exploitation from mutual service, and assumes, on the instinctive level, the form of a true alliance. For instance, in tropical South America a large brown Camponotus and a small dark-coloured Crematogaster jointly inhabit a curious arboreal nest which consists of a tunnelled ball of earth built round a tree-branch. (Such tree-nests of earth are usually overgrown with a fine "garden" of epiphytic plants, but these appear to owe their presence merely to accident, and to play no part in relation to the life of the ants.) The small-statured ant-people inhabits the outer layers of the nest, and its neuters rush out in defence whenever the nest is disturbed. The larger species lives in the centre, and, though extremely formidable, only emerges if the danger is serious. There is thus a division of labour between the two species analogous to that which obtains between workers or small skirmishing soldiers and large, heavy-armed soldiers of one and the same species. Even in this case, however, the young of the two species are kept and tended separately, although the adults continue to utilize the military advantages of the alliance by foraging together.

What is, in one sense, a further step has been taken by certain small ants such as Leptothorax, which, like many human parasites, get their living by making themselves agreeable. They make their galleries in the walls of Myrmica nests, but obtain their food directly from the Myrmica workers. This they do by creeping up on to their hosts' backs and licking away at their bodies and especially their mouth-parts. This titillation seems to please the Myrmicas, for they respond by regurgitating food for their little menials. These Leptothorax are thus in precisely the same boat as many of the beetles and other creatures which ants welcome in their nests, obtaining board, lodging, and tolerance in return for services rendered (Chapter VIII.). Their interest in the present connection comes from the

fact that, though in normal conditions they keep their own young stuck apart in chambers built by themselves, they can be induced, by being kept in artificial nests without any earth, to allow the Myrmicas to mix the broods of the two species. It is also interesting, as an example of ant plasticity, to find that, if they are kept by themselves in an artificial nest, they will after a time take to eating honey, insects, and other usual articles of diet, in spite of the fact that normally they take nothing but the product of the Myrmicas' social stomachs.

True slave-making has been evolved separately in the Formicine and Myrmicine ants. It was first observed by the younger Huber over a century ago, in the red slave-maker *Formica sanguinea*. The full biological meaning of its habit of raiding the nests of its black congener, *F. fusca,* for slaves, however, was not appreciated till nearly a hundred years later, when Wheeler found the clue to it in the habits of the queen. She is less independent than most other ant-queens, in that she is unable to found a colony by herself. After a successfully consummated marriage-flight she may either make her way into an established nest of her own species, or else into one of *F. fusca*. In the latter event, she collects a pile of pupæ, and kills any of the workers that attempt to take their possessions back. By the time the adult *fusca* workers hatch out, the robber queen must have acquired the proper smell, for they are wholly friendly, feed her, and tend the larvæ which hatch from the eggs she lays.

When adult *sanguinea* later emerge from the queen's own eggs, a mixed colony results. In different geographical sub-species of *F. sanguinea* different grades of slave-making propensity exist. In one the workers have none of it, and the mixed colony turns into a pure *sanguinea* with the death of the black workers kidnapped by the queen. In most, however, the *sanguinea* workers make periodic forays on nests of pure *fusca,* bringing

back stores of worker larvæ and pupæ. This habit is given up by some races when the colony has reached a certain size; but, finally, in still others is permanently continued. The black workers in the mixed nests are not slaves in the ordinary human sense, since they do not perform more menial functions or in any way occupy a lower position in the social scale than the red workers; they are rather like captives given complete equality with their captors, but forced to change their nationality.

The fact that some queens, like her of *Formica sanguinea,* are unable to store in their bodies enough food to feed their first batch of young is the first step towards slave-making. In one remarkable case—Bothriomyrmex, temporarily parasitic on Tapinoma—the foreign queen approaches the host nest, and is then forcibly seized by the workers. Once in the nest, the workers often attack her, but she then leaps up on to the back of one of the pupæ or, often, of the host queen, who is a good deal larger than she. Apparently, in those positions her foreign smell is masked by the local odour of patriotism, for she is then perfectly safe, just as on another plane of behaviour a spy may be safe in a foreign country if he masks his real feelings by assumed devotion to the local institutions. She spends more and more time on the back of the host queen, slowly but surely accomplishing her task of sawing her head off. By the time this is achieved she has herself acquired the nest-smell, and is adopted, with the usual result that the Tapinoma workers rear up a brood of aliens, and the colony is eventually converted from pure Tapinoma to pure Bothriomyrmex.

Polyergus is allied to Formica; it also enslaves *Formica fusca,* but begins where the red slave-maker leaves off. The young queen here invariably invades some small colony of *fusca,* kills the queen by piercing her head with her mandibles—definitely adapted to such pugnacious acts by their pointed strength—and is

then adopted by the workers. The Polyergus workers are equally brutal in their raiding methods. The raids —always, for some mysterious reason, executed after midday—are highly organized, and any resistance on the part of the workers in the *fusca* nest merely results in the Amazons—as Huber christened the Polyergus—killing them with one nip of their sabre-jaws. Usually the *fusca* adults, whether as the result of instinct or experience, turn tail and leave their brood to the mercies of the hostile army. There is, in this case, a much greater division of labour between the captives and their captors, and the former more nearly merit the name of slaves. Polyergus' jaws are of purely war-like function, of no use in digging or capturing prey; they are a military aristocracy and do nothing but go raiding, while the *fusca* stay behind and do all the work of making the nest, obtaining food, and tending their captors' young. The masters have gone so far on the way to parasitism that they cannot feed themselves. Huber shut up thirty of them with some of their own young and plenty of food, but no slaves. Some actually died of hunger, and none even attempted to eat. A solitary slave was then put in. She at once fed the others, tended the larvæ, and began building operations. Another observer put a pile of sugar near a nest. Soon a number of slaves were gorging away at it. Some of the Polyergus then came out and pulled at the legs of the slaves. This was apparently a reminder of their duty, for they at once began to regurgitate their masters.

When the colony migrates, it is the slave-workers which carry their captors to the new nest, while in the *F. sanguinea* it is the slaves which are transported by the masters.

Finally come the ants which have reached the last stage of parasitism, and with it have lost the power of producing workers. The best known is Anergates, parasitic on Tetramorium, but the step has been taken

independently four or five times. The queen of Anergates, as in all these permanent parasites, secures her adoption by the host-workers by some unknown means; and then becomes swollen with eggs. The workers later, for reasons again unknown, murder their own queen. They tend the offspring of the usurper, all of which turn either into queens or males. The males afford a good example of what is known as neoteny, or reproduction while the body as a whole is still in an immature condition, since the general characters of the pupa-stage, including winglessness, are carried over into the adult phase. Mating must then take place within the nest, and is always between brother and sister; after mating, the winged queens fly out to seek new Tetramorium thrones.

It is interesting that most of the parasitic species of ants, and all those workerless permanent parasites, are scarce and very local; it is also interesting that the host is in every case closely related to the exploiter—this latter fact being explicable through the necessity for the workers to have nursing instincts adapted to the needs of the parasites' larvæ and pupæ.

CHAPTER VIII

GUESTS AND PARASITES

In one strange respect the social insects, notably the ants and the termites, have attained a specialization not reached by man; and that is in the number of animals of other sorts which live in their communities, and are so closely adapted to such life that they can exist nowhere else. It is, of course, true that in or

about the habitation of man there are to be found plenty of animals of other kinds—physical parasites like flea and bug; economic parasites like rat, mouse, and cockroach; commensals like the cricket on the hearth or the house-martin; animals domesticated for food or draught, like hens, pigs, or horses; domestic companions and guards like the watch-dog; and pets like lap-dogs or parrots or goldfish. But the state of affairs is very different in the ants' nest. Their domesticated aphids and scale-insects we have already considered. There are no other kinds of domesticated animals, and no ant-pets deliberately taken into captivity because of their attractiveness. The same difference between insect and man, which has so often cropped up, is at work here again. Most of these "ant-guests" have been adapted to their mode of existence by natural selection, and their whole structure and instincts have been hereditarily modified. As we shall see, the tastes and aversions of the ants have doubtless contributed to the moulding of the guests' germ-plasm, but this moulding has been indirect, and there exists among the ants nothing similar to our conscious artificial selection, when we purposely breed only from those specimens of our pets or domestic animals which best please us, nor to an organized campaign against parasites or pests, like the ridding of Scotland of wolves or the Panama Canal zone from mosquitoes.

Finally, most of the aliens are of a size comparable to the ants themselves. If we imagined that in England our houses were, against our wills, inhabited by cockroaches as big as wolves and house-flies like hens; and that there were crickets to whose presence we were indifferent, although they were the size of our own children; and also pet-like creatures whom we liked because they rendered us some agreeable service, as it might be parrots which had the instinct of scratching our backs for us, or giant cats which we

allowed to eat our babies in their cots because they secreted hot rum-punch or some equally fascinating liquid; and that in France, say, and the United States there were similar sets of animals, willy-nilly sharing men's houses and reproducing there, only all belonging to different species from those in England; and, finally, that they were all incapable of existing permanently anywhere outside our houses; then we should begin to get some idea of the menagerie of guest-animals in the habitations of ants.

The evolutionary method which a great many of these creatures, and probably that numerous host to which the ants show active friendliness, have adopted is to exploit their hosts' peculiar form of greed, which, in turn, has been specialized as a consequence of their trophallaxis. They have developed glands producing secretions similar to those exuded by the ant-larvæ themselves, and in return for the privilege of licking up these tasty juices the workers will feed them just as they feed the larvæ. Sometimes the secretions of the guests must be possessed of new and overpoweringly attractive properties to the taste, so that the nurses even neglect their proper charges in favour of these aliens. We know, alas! of human parents who will neglect their children for drink, but this is as if a mother were to abandon her baby for the charms of gin exuded from the body of a changeling.

Wheeler admirably sums up the situation as follows: "Any insect possessed of these glandular attractions . . . can induce the ants to adopt, feed, and care for it, and thus become a member of the colony, just as an attractive and well-behaved foreigner can secure naturalization and nourishment in any human community. But the procedure among the ants is more striking because the foreigners are so very foreign. . . . Were we to behave in an analogous manner we should live in a truly Alice-in-Wonderland society. We should delight in keeping Porcupines,

Alligators, Lobsters, etc., in our homes, insist on their sitting down to table with us, and (in some cases) feed them so solicitously that our children would either perish of neglect or grow up as hopeless rachitics."

Perhaps the strangest of these alien exploiters are the Staphylinid beetles, Lomechusa and its relatives. The habits of Lomechusa were brought to light by the Jesuit entomologist Wasmann. It lives exclusively in the colonies of the red slave-maker, *Formica sanguinea*. The adult beetle solicits food from the ant-workers by stroking them with its antennæ; its abdomen is covered with bunches of golden hairs, called trichomes, which surround the opening of special glands and act in lieu of teats for their secretions; the beetles present them to the ants, working their abdomen forward over their back; and the ants eagerly suck off the oily secretion, rewarding the beetles with regurgitated food. The grub-like larvæ apparently exude fatty secretions of much price, for not only are they fed with regurgitated food by the worker-ants, not only are they tended and moved about with the ants' own brood, but are allowed to eat the ant-larvæ. Indeed, the ants appear to prefer the Lomechusa grubs to their own, with the result that a large part of the brood dies.

It is in colonies heavily infected with Lomechusa that pseudogynes (p. 22) are produced. It has been supposed that the ants eventually realize the shortage of workers and attempt to convert queen larvæ into workers by altering their diet—but too late to have effect. Another possible explanation is that the queen larvæ, being neglected, fail to get the right food and are therefore switched over towards the worker type of development. These pseudogynes, which usually comprise five per cent. and may reach twenty per cent. of the population of an infected nest, are described as "lazy, cowardly, and incompetent." When a nest is

heavily infected it can produce no queens, and will soon die out.

It might be thought that the whole race of red slave-makers would be on the road to rapid extinction owing to the beetles. But, as a matter of fact, the species is abundant and prolific, the parasites' infection only local and sporadic; and this is true, not only of this host and this parasite, but of all other deleterious ant parasites and their hosts, whether the parasites be insects of other groups or ants of slave-making or parasitic habits. The greatest danger to a deleterious parasite is to be too effective in inflicting harm upon its host. For if the host decays, it decays too; if the host is extinguished, it, too, becomes extinct. In general, it is the very widespread successful or plastic species that supports the greatest number of kinds of parasites, because they are less likely to succumb under the burden. The extraordinary abundance of gall-producing insects that affect the oak is an example from another group. In addition, if the parasite is not to kill itself by killing its host, its numbers must be kept down, either by the host's acquiring partial immunity or by great difficulties of dispersal from host to host, or by some other means. Thus, as a general law of parasite existence, the parasite must be less numerous or in some other way less biologically dominant than its host.

The check on Lomechusa is a very curious one. The ants treat the beetle-grubs as they do their own brood. This ant buries its full-fed larvæ in the soil; here they spin cocoons, and are then, as pupæ, dug up again, cleaned, and piled in special chambers. Now, the Lomechusa larvæ, though they, too, must be buried to pupate, spin no cocoons, and infallibly die if dug up again; so only those few buried beetle-pupæ which the ants fail to unearth succeed in turning into adults, and the population of Lomechusa is thus regulated down to sufficiently low proportions.

The closely-related beetles Atemeles and Xenodusa are interesting in that they have two hosts: in the summer they live in Formica nests, but take up their winter quarters with species of Camponotus, the carpenter ant. They only breed, however, in the summer, so that the Camponotus does not have its brood affected, and produces no pseudogynes.

Several hundred species of befriended guest-beetles are known from ants' nests. All of them possess the special glands and their teat-like trichomes. Curiously enough, the hairs of the trichomes are almost always yellow, and the general colour of the beetles an oily red. In addition, their jaws are often highly specialized to feed on the liquid pumped up by the ants, and their antennæ modified to imitate the soliciting action of the antennæ of other ants. The addiction of the ants to the liquors and rich buttery sweetmeats which these produce is revealed in the way in which, at the threat of danger, they seize the beetles and carry them to safety.

Other kinds of insects also exploit the ants' greed. During the last decade, for instance, it has been discovered that, of all unlikely creatures, some of the lovely blue butterflies (*Lycænidæ*) are, at one stage of their development, ant-devourers. The caterpillar lives the usual vegetarian caterpillar life until it is half grown. It then descends from its food-plant and stations itself in an ant-track. It appears to produce desirable secretions, for the ants, on finding it, carry it off to the nest, where it lives at the expense of the community, giving only luxuries in return for necessities, until it is time for it to pupate.

Other ant-guests, not being ambulatory bars or confectioners' shops, are treated with hostility by the ants, and must gain their living by stealing and escape destruction by agility or strong defence. For instance, *Lepismina,* a primitive wingless insect of the silver-fish type, steals impudently from Lasius. Janet has described

the scene when the worker Lasius bring back food to the nest. The *Lepisminas* at once begin to show by their excited movements that they smell something. The returning workers meanwhile begin to regurgitate food to their stay-at-home sisters. As the food is being transferred, feeder and fed face each other, with the fore-parts of the body raised. A thief approaches such a couple, crawls below their heads, suddenly snaps up at the liquid as it passes from mouth to mouth, and rushes off. The ants, being in rather a delicate pose, are usually not able to turn in pursuit before the *Lepismina* is out of reach; and, in any case, it is covered all over with smooth scales, which render it hard to catch.

Another thief-guest relies on mechanical protection. It is compassed all round with a series of long scales, somewhat in the shape of the long caparisons worn by mediæval horses in the tourney; some of these scales can also be thrown forwards to form a more or less tubular protection for the proboscis. In addition, there are still bristles which protrude straight out from its flanks. It, too, steals from the workers as one is feeding another, reaching up with its protected mouth. If an ant tries to get under its defences, the bristles act like cats' whiskers to give notice of the attack, and the scales on that side come down flat on to the ground, conferring upon the attacked side of the animal the properties of a tank.

Then there are parasites—thieves, if you will—of which the ants take no notice. Wheeler has described the larva of a little fly (*Metopina*) which exploits an ant of the genus Pachycondyla. The fly-grub clings like a collar round the neck of the ant-grub; the latter is fed by having pieces of insects placed in a natural trough on its ventral side; and on this happening the Metopina uncoils and reaches out for a share. Apparently it acquires the smell of its host, for the ants do not notice it at all, and clean it with the rest of the

ant-grub. Its adaptation to safe emergence deserves mention. Its development is adjusted to that of its host-grub, and when the ant-larva pupates, the fly-larva, which is, of course, enclosed in its host's cocoon, moves to the hind end and there pupates also, forming a puparium very much flattened against the cocoon wall. When the callow adult ant is ready to emerge, the workers bite open the front end of the cocoon and pull it carefully out, and the apparently empty cocoon is then taken off and thrown on the refuse-dump. The fly's pupal period has been adapted by natural selection to be longer than the ant's; thus when the fly emerges, it finds no obstacle to a safe exit. Here, again, the parasite merely takes toll from the ants' excess; there is no sign of its inflicting any damage on the individual larva it steals from, or on the colony as a whole.

The most extraordinary of tolerated guests is perhaps the externally parasitic mite Antennophorus, some of which infest those same Lasius which we recorded as being almost blind and keeping white ant-cows underground. The mites are quite large in comparison with their hosts, much like a cat or a smallish monkey in relation to a man, and up to four (or rarely six) may be found on one ant. They behave in a remarkable way as regards the positions they take up, always placing themselves so that the ant's balance is not upset. When there is one, it is always under the chin; if a second comes, the two move to the two sides of the abdomen; a third will occupy the place under the head; a fourth will occupy one side of the head, while the third will move to the other; a fifth will once more attach itself below the chin; and the rare sixth will occupy the only vacant space on the top of the abdomen.

The ones attached to the head feed on regurgitated drops as they pass directly between the mouths of their own St. Christopher and another ant; or they

cause it to "cough up" for their sole benefit by stroking it with their fore-legs, which are moulded into a passable semblance of ants' antennæ. Those mites which ride on their host's abdomen stroke other ants, or snatch at drops passing between other worker-pairs.

The strange fact is that the mites appear not to produce any secretion in exchange; and the ants try to throw off their riders when they are mounting, though afterwards they tolerate them once they have settled into their positions of equilibrium. One can only conjecture that the mites have the nest-smell, that once in position they are not much of an annoyance, and that their soft strokings are like enough to the solicitations of other workers to delude their hosts. Wheeler suggests that the blind ants feel towards them as we might to pleasant pets; this *may*, of course, be so, but seems on general grounds rather unlikely.

These instances constitute but a sample. Already more than 2,000 separate species of ant-guests are known, somewhere about half the number of known species of ants; and these include representatives of mites, spiders, crustacea, and most of the orders of insects—indeed an amazing menagerie! "Where the feast is, there shall the vultures be gathered together"; and the very success of ants has led to their being exploited by these hordes of other creatures.

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CHAPTER IX

TERMITES OR "WHITE ANTS"

We cannot exclude termites from our survey. For though actually quite unrelated to true ants, they are so like them in many ways as to have earned the name of "White Ants." The organization of their colonies is very like that of ants' nests, and yet sufficiently different to afford much food for reflection. In many ways they excel even the ants in strangeness of habits and social organization; but for all their abundance and their marvels of structure and instincts they have not attained the same supremacy in the biological world. They still bear the marks of their origin from an altogether lowlier stock of insects; hardly any of them can tolerate daylight, and they have not been very successful in pushing far out of the tropics.

They belong to the Isoptera, one of those primitive insect orders which have no true metamorphosis, but hatch from the egg in a form essentially like the adult. Almost all of them are tropical or sub-tropical. A few penetrate to higher latitudes; but in striking contrast to the ants, there are not more than forty species or so in the United States, and only two of them reach the parallel of Boston. Not only this, but whereas the highest sub-families of ants are the most successful in invading cool climates, the highest family of Termites, the Metatermitidæ, is almost exclusively tropical.

They may be divided very conveniently into four families, arranged in a single scale of progressive specialization. One of these, the Mastotermitidæ, comprises but one living species confined to Australia, though fossils show that in the early tertiary epoch the

family was widely spread in Europe, and probably elsewhere. Thus Mastotermes has the same sort of relation to higher Termites, both in structure and distribution, that the duckbill Platypus has to the remainder of living mammals; and just as the Platypus betrays the relationship of mammals to certain reptiles, so Mastotermes shows that Termites are sprung from Orthopteran ancestors, since it betrays close affinities to a family of cockroaches, the Protoblattidæ, which died out in the Permian period.

All Termites are fully social, with neuters doing the work of the colony. But there are two, and probably three, fundamental distinctions between their social organization and that of ants, bees, and wasps. In the first place, the colony is always started by a "royal pair," a queen together with the male who has fecundated her, instead of by a solitary queen. Secondly, the workers, and other neuter castes when present, are of both sexes in equal numbers, instead of all being sexually-arrested females. And, thirdly, it is probable that the various main castes at least are all determined by heredity, and not by means of differences in diet. Thus the sexes are of equal social importance instead of the males having a purely reproductive function; and, if the third point be established, the social organization is in a sense on a lower level than that of ants or bees, since the determination of the various castes depends wholly on a germinal mechanism, and not at all on the instincts of the nurses.

There exists a complete gradation from colonies with only a few score individuals, and only one type of neuter caste, up to communities which pass the million mark, outdoing even the ants in numbers, and exhibit an extraordinary polymorphism. In the most developed communities there exist the following types: (A) *Reproductive caste.*—(1) First form reproductives ("queens" and "kings"); (2) second form

reproductives, or substitute queens and kings; (3) third form reproductives, or worker-like substitute queens and kings. (B) *Worker caste.*—(4) Workers, male and female. (C) *Defence caste.*—Either (5*a*) soldiers or else (5*b*) peculiar snouted defence forms called the *nasuti* or "nosy ones," these also both male and female. This makes ten castes, five male and five female. In addition, both the workers and the soldiers may be differentiated into sub-castes, differing just as in ants in size and proportions of heads and body, bringing the total numbers of distinguishable forms up to twelve or fourteen.

In almost all Termites the true king and queen alone among the castes are fully pigmented and capable of facing the light of day. They are winged, but, like the queen ant, break off their wings on descending to earth, after leaving the nest on their one flight. This flight is not a true nuptial flight, but a dispersal flight, since mating takes place, not in the air, but after they have descended (in couples) to the ground, and shed their wings. Later, the queens grow to an incredible size, flabby white sausages over four inches long, and proceed to lay an egg about every two or three seconds for the remainder of their natural life.

The second form reproductives have all the characteristic organs of the reproductives, but reduced in size or quantity, less pigment, smaller brain, eyes and reproductive organs, and rudimentary wings; while the third form reproductives carry the loss a step further, and have no wings, scarcely a trace of pigment, rudimentary eyes and further reduced brain and gonads. These two castes, of substitute queens and kings, are what we have called neotenic (p. 55); they carry over the more primitive characters of the later or earlier larval stages into the adult reproductive phase; their origin would be accounted for on the hypothesis that all processes of differentiation, save the one concerned with ripening the gametes, were slowed down during their

development. Their function in the colony is somewhat obscure. They are usually believed to be reserve reproductive units, ready to take the place of the true kings or queens should they die; but this is not certain, nor whether they, as well as the full kings and queens, normally exercise their mating instincts. In the colonies of some species the true queen never develops, but her place is taken by a harem of second form females, sometimes over a hundred in number.

The workers are white and pigmentless, lack wings, and their eyes are rudimentary or absent; like the independently evolved worker-caste of ants, they are chiefly concerned with nest-building, food-seeking, and food-distribution, and the toilet of the other castes; but unlike worker-ants, they have brains smaller than the reproductives. The soldiers are wingless, with huge heads and jaws, and usually use them in the defence of the colony. They have some hardened and pigmented skin, but only on the head; and thus they are like the goblins in McDonald's "Curdie and the Goblins," cast-iron in the head but soft and defenceless elsewhere. Since they, too, are permanently subterranean, their eyes are degenerate. The *nasuti* also defend the colony, but in a way which has the same sort of relation to the brute strength method of the soldiers as has chemical warfare to bayonet fighting. Their jaws are minute, but in return the frontal gland which most termites possess is in them much enlarged, placed conveniently forward at the tip of the snout, and made to secrete an adhesive liquid which certainly can immobilize the enemies by sticking their limbs and antennæ together, and perhaps has poisonous properties as well.

In some forms the secretion of the *nasuti* appears to be used to dissolve hard substances which are in the way of the workers when building; it is stated that even concrete may be eroded in this way!

Miss Thompson has discovered that the young

reproductive forms can be distinguished from the worker or soldier at hatching, and probably the worker from the soldier also, by differences in the size of brain and eyes. This would make it practically certain that at least the three main castes were predetermined at the moment of fertilization, just as are the sexes in most animals, or the different forms of flowers in Primrose or Loosestrife. The sub-castes or workers and soldiers, however, are presumably determined, as in ants, by differences in the amount of food secured by the growing young combined with differential powers of growth in different parts of the body. The origin of the subsidiary royal forms is unknown.

How the genetic machinery works we have at present not an inkling. It has been further asserted that while the first form royalties can reproduce all the castes, the second form reproductives cannot give rise to the first form, and the third form neither to the first nor to the second form. The mechanism underlying this is equally obscure, though it, too, might be genetic in nature, the two substitute forms being recessive.

The food economics of the termitary outdo those of the ants in strangeness. To start with, the higher, wood-eating termites are unable to digest their food unaided; they have to rely on certain parasites turned helpers. These symbiotic inhabitants of their gut are ciliates called Trichonymphids, large for single-celled animals, with bizarre movements and a very peculiar arrangement of their cilia. They are normally only found in the interiors of the adult workers and soldiers, not in the young, nor in the reproductives.

Now, in higher termites, the whole termitary derives its existence almost entirely from wood, and other dead plant tissues which consist either of cellulose or the modified woody cellulose, lignin. Neither cellulose nor lignin, however, are attacked by the digestive juice of any animal higher than snails. The

Trychonymphids, on the other hand, produce cellulose-splitting ferments; they thus supply their hosts' deficiencies. The termites supply the food for both partners; the protozoa chemically chop it up until it is soluble, and both live on the products of their joint activity. The reason why Trichonymphids only live in the workers and soldiers is doubtless that these alone eat raw cellulose, the other castes being supplied by them with liquid products of digestion.

Experiment has proved what observation suggested —the indispensability of the Trychonymphid for the termite. The protozoa cannot stand such pure oxygen; in an oxygen atmosphere all of them die in a few days, while the termites themselves are quite unaffected. Workers thus rendered protozoa-less die of starvation in a few weeks, although provided with all the wood their hearts could desire. They devour the wood with all their ordinary appetite, but nothing happens to it in their interiors, and it passes out unchanged, without their profiting from it in the slightest. If, however, they are artificially reinfected, they become capable of digesting their food once more.

The food, once digested in this way, begins a direct or indirect circulation through the colony, compared to which the ants' methods are primitive. This food circulation has been likened to the circulation of blood and lymph through our own bodies; and, though the comparison is but rough, yet it is exact in one fundamental respect—the food does constitute a nutritive stream, by which the various units of the whole are bound together in mutual dependence. First, as in ants, the termite workers regurgitate, but what they regurgitate is only partially digested. Secondly, they can dispense more fully digested food, but this must be done *per anum,* only part being absorbed in its passage through the intestine, and the rest passed out behind for others' consumption. Thirdly, some of the absorbed food is worked up in

the " salivary " glands into a liquid with nutritive and doubtless pleasing properties, and drops of this are secreted for others. It seems probable that the different castes exude different substances, and that, in the darkness of the nest, they are recognized by their taste. The full-grown first form queen appears to secrete the most delicious exudate of all, and is invariably seen to be surrounded by a regular court of workers, who, however, are not doing obeisance, nor even tending her, but licking up the royal juice as it exudes, sometimes with such gusto that they perforate the royal skin.

Just as in ants, this fondness of the termites for such rich food has led to their exploitation by a number of guest-insects who have mastered the secret of producing similar substances. Presumably in accordance with differences in the construction of termites' mouths from those of ants', their guests have not developed the teats of hairs characteristic of ant-guests, but instead have produced thin-walled, lickable structures, swollen bellies, or special protrusions of the body. In addition, a great many have acquired the physogastry or extreme swelled-belliness characteristic of the full-blown termite queen. This is usually produced by the enlargement of the fat body, but may be due to enlarged gut or gonads. With increase of abdomen, there generally goes decrease of head and eyes, thorax and wings. A curious fact about the guest-beetle Spirachtha is that it appears to hatch out in more or less beetle-guise, and only (like the termite queen) to acquire the swollen belly and lickable outgrowths later.

It would naturally be supposed that this swelling was directly concerned with the production of more fatty delicacy, and more surface off which it could be licked. However, it appears to be the fact that some of the insects which are never licked, but to which the termites are either indifferent or hostile, also

acquire physogastry. It has been accordingly suggested that physogastry is in part due to some substance in the food acting like a hormone, and that selection has later stepped in to exaggerate and utilize the result.

There are no examples known of slave-making or workerless parasites among termites; in fact, the social insects most frequently nesting inside or near termitaries, and profiting by the shelter, protection, and food provided, are ants. A few termite species, however, are thieves, and some *Microtermes* steal fungus and prepared "soil" from the vegetable-gardening termites *Odontotermes* and with the spoils make gardens of their own.

The nests of termites are on the whole more interesting than those of ants. This is natural, since the termite is so intolerant of light and air that, unless it lives wholly under the level of the soil, it requires something more solid and permanent. If, as from one point of view we are justified in doing, we regard the termite colony as one individual, then the nests of higher termites are to be compared with the thick armour-plate of giant crabs or tortoises or some dinosaurs, or the shelly fortress of an oyster or a conch. But armour-plate, however successful an expedient for the time, in the evolutionary long run leads animals into a blind alley. The more efficient the dinosaur's armour, the less need of speed, brain, or acuteness of sense to avoid enemies; the more colossal and steely-sided the termitary, the less readily can its inhabitants change their abode, the less are they forced into a healthy give-and-take with the forces of Nature. Thus in the long run the termites have become a race of gnomes, stranger and more remote from the main stream of life than ants or bees, supreme within their own limited darkness, but in a sense aliens in the greater world.

The lower termites in general make nests not unlike those of ants, diffuse tunnellings below ground,

or in decaying logs and stumps. The higher types, on the other hand, build what have been styled concentrated nests, definite edifices sharply marked off from the rest of the environment. Perhaps the most striking are the giant earthen termitaries of the African grasslands, which, gradually built up over the original tiny subterranean chambers excavated by the royal founders, may reach a height of twenty feet and more, so strong in construction as to be almost indestructible with anything less powerful than dynamite. Very similar nests are to be found in Australia, too. In the hottest part of this latter continent some species construct long, thin, wedge-shaped buildings, which are called compass-nests owing to their always being aligned north and south; this arrangement doubtless is an adaptation to the great heat, since less surface is thus exposed to the midday sun. In Africa, strange stalked nests are found, with a mushroom top apparently serving as an *en tout cas* to protect both against sun and rain. Other nests from the rain-forests of the same continent bulge out like a cluster of sausages from the trunks of trees, and are protected from the rain by a whole series of inverted V's of cemented wood-pulp built on to the tree-trunk above them. While the ground-nests are usually built of earth, the material of the tree-nests is for the most part chewed and semi-digested wood cemented with saliva into a paper-like mass. Usually they are round or oval, and may reach the size of a respectable barrel. Termitaries, unlike ants' nests, never have any visible entrances. This is owing to the light-shunning of their inhabitants. The termites either burrow through the surrounding soil or wood, or, in many of the higher forms, though they travel on the surface of the soil, run up tunnels over their roadway as they advance.

These tunnels may be several score yards long, and by their aid the colonial organism extends its tentacles

in every direction. When a large termite colony by this means penetrates into a house, its ravages may for a long time remain unsuspected, since the workers will devote themselves to eating out the inside of every wooden object available. Eventually, they will reduce walls, floor-planks, tables, and chairs to a mere shell, and the householder is made aware of what has been going on by the collapse of his furniture or his house.

Owing to these habits, termites are much more destructive than ants. It is, of course, not only the woodwork of houses which they invisibly devour. Fences, railway-sleepers, telegraph poles, boats, landing-stages, bridges—all are grist to their mill. But it is not merely material civilization whose spread they retard. Paper, too, is made mainly of cellulose, and the addition of printer's ink unfortunately does not render it unpalatable to the termites. Thus some of their most serious ravages are committed on documents and books. Von Humboldt records that, when he was in the hotter part of South America he rarely saw any book over fifty years old, the rest having gone to feed termites. It has been suggested with a good deal of reason that this is one (though doubtless by no means the only) cause of the slow development of culture in the tropics; and it is certain that any tropical nation that wants a flourishing and enduring civilization will have to construct, what some have already made a beginning with, termite-proof foundations for its buildings, more particularly the buildings where its libraries and its archives are housed, and for any structure in which any degree of permanency is required.

On the credit side of the termites' account, however, must be entered the fact that, unlike ants, they are not only not deleterious but actually beneficial to agriculture. In temperate regions, as Darwin showed us, earthworms perform a very important task in preparing and renewing the soil for plants. Termites per-

form a very similar function in the tropics, but probably on a greater scale, and certainly with greater rapidity. Their tunnellings aid mechanically, their protozoa digestion chemically, in hastening the disintegration of those resistant substances, cellulose and wood; and in this way much of the capital of life, which would otherwise stay locked up for years in a strong-box of chemical unavailability, is by them rapidly brought back into circulation.

Strange to say, fungus-gardening has arisen in termites as well as in ants—a good example of independent evolution which may be taken to heart by some of the more radical diffusionists who maintain that in human culture nothing has ever originated more than once. The fungus-gardens may reach an even greater size and perfection than in the ants; the nests containing them are sometimes provided with chimney-like structures, which are probably ventilating shafts designed to help in the regulation of temperature and moisture. It has at any rate been shown that the diurnal rate of temperature in the nest is only 9° C., when that outside is over 20° C. The workers and soldiers keep to the more solid diet of cellulose, and leave the fungus to the reproductives and the young. The young use the gardens as a combination of pasture and nursery, and present a pretty enough picture as they browse—white miniature lambs against herbage of equal whiteness.

It can be prophesied of the termites in their armoured colonies, with even greater assurance than of the ants, that they have reached the end of their evolutionary tether, and will continue, as a group, with no essential change and no real progress. Holmgren, one of the authorities of the group, has pointed out that their evolution is accompanied first by that specialization of their societies which has already been mentioned, secondly by an enlargement of their brains, and thirdly by a degeneration of their bodies.

This is a fate which has often been prophesied for the human species. It remains to be seen whether the fact that man lives partly on the level of reason and foresight will enable him, through sport, physical exercise, and eugenics, to surmount the danger.

CHAPTER X

INSECTS AND MAN

So our brief review of the ants and termites comes to an end. We are now in a better position to judge of the fallacies into which so many writers on social insects have fallen, to some of which reference has been made in the introduction to this book.

A few have been guilty of gross over-simplification. Bethe, for example, wished to make of ants and bees the merest reflex machines, incapable of profiting by experience or recognizing the locality of their nests in any way at all similar to our recognition of familiar spots. Others, again, would have it that they were wholly colour-blind, which, if true, would have robbed the brilliant colouring of flowers of all biological meaning.

But the majority adopt a more popular and a more insidious view. They either turn insects into miniature human beings, or else ascribe to them wholly magical attributes. Bethe himself was obliged to postulate in bees a mysterious sense of direction which operated through none of the ordinary channels of sense; and the powers ascribed to instinct by writers such as Fabre would enter the realm of miracle—if they were

true. On the other hand, lay writers, like Maeterlinck in his book on *The Life of the Bee,* and still more that on *The White Ant,* ascribe all the achievements of insects to intelligence, and draw invidious comparisons between their minds and that of man. It would really seem that such writers have never heard of Darwin, or at least never read his works or even a modern summary of what is meant by Natural Selection; that they are ignorant of ordinary physiology, and unaware of the extreme complexity which wholly mechanical and non-conscious behaviour can reach in ourselves.

Maeterlinck, for instance, says that the termites are more intelligent than we are because they have found out how to digest wood, to dissolve concrete, and can mould the bodily form of their citizens at will, sterilizing them, turning them into born soldiers, or making them mere egg-laying machinery. But the termites can no more help having the wood-digesting protozoa in their gut than dogs can help having worms, and, since no one has ever thought of ascribing to human intelligence the existence of the admirable ferment trypsin in our pancreatic juice, or the fact that our eyes are constructed as very efficient cameras, there is not the slightest reason for doing so in the case of the termites' chemical achievements. In termites, too, there is every reason to suppose that all the castes are predetermined by heredity; if this were so, their "intelligence" in possessing royals, soldiers, and workers would be precisely on a par with the "intelligence" of human society in generating people who are fair-haired or dark-haired, tall or short, temperamentally athletic or intellectual.

Even where, as in ants and bees, the differences between neuter and queen are determined by feeding, the whole capacity for reacting to the two diets in these two different ways is given by heredity, as is also the instinct of the workers to feed the young in these par-

ticular ways—for they will do so without any training —and the only point left to be decided by intelligence is the relative numbers of queens and workers to be produced. As a matter of fact, we do not yet know anything as to how the right proportion of the castes is arrived at, and it may even be accomplished by some almost automatic response. In any case, the actual bodily shape of the different castes has been arrived at through the operation of natural selection, and is wholly different from the moulding of his domestic animals and plants achieved by man, as when the fancier breeds a new strain of fowls up to a standard previously laid down, or Sir Reginald Biffen deliberately sets about creating a new sort of wheat.

Finally, there is another fallacy which from time to time crops up. We are told that, as we elaborate our civilization, as we mechanize it by trusting to the achievements of applied science, as we specialize more and more in occupation, we are inevitably heading for a condition in which our society will come to resemble an enlarged ants' nest or gigantic termitary. For this prognostication, too, which has been recently advanced, among others, by Dean Inge, there is no shadow of biological support. Partly, it seems, this view is based upon conscious or unconscious Lamarckism; it is felt that, if we specialize, the structure and modes of thought of our offspring will gradually become fixed in the grooves of society's various specialisms. The modern study of heredity has luckily proved the baselessness of any such fear. For the rest, it is based on a particular theory as regards the course of evolution. All types or groups of animals and plants—say the upholders of this view—pass through a period of rapid evolutionary change to reach a later phase of stability. The first phase is characterized by great plasticity of the germ-plasm, while in the second it becomes fixed and resistant to change.

Now, in the first place, this idea of the plasticity or

fixity of the germ-plasm is pure hypothesis, proposed as a possible explanation of the undoubted fact that many types, after rapid initial evolution, do settle down later to a slowing or stoppage of progress. But it by no means follows that the cause of this resides in the germ-plasm; it may just as well depend on the animal having become so specialized that few or no changes which actually take place in the germ-plasm could be of any biological advantage. And, in the second place, the fact that rapid rise, followed by stability and finally by decline, has frequently occurred during evolution is no reason for erecting a universal law upon the body of the facts, any more than the frequent rise, stable maturity, and eventual decline of nations is any valid reason for supposing that such a cycle is a necessity for all nations.

It is always possible, in the past instances of such evolutionary cycles, to assign reasons for the slowing down of progress and the eventual decay or extinction of the group. The limits of physical specialization account for the one, and the rise of new groups from an initial stage a step higher than that of the earlier group, a rise frequently aided by cosmic accidents such as changes in climate or in the distribution of land and water, accounts for the second. If one specialization can be achieved without enslaving the body and turning it into a particular kind of tool-box, and progress, too, can take place by the aid of conscious methods, by improvement of tradition and social organization, and if necessary by deliberately controlled breeding, the whole case is altered, and the limitations fall to the ground like the walls of Jericho at the blast of the Israelites' trumpets. Man alone among animals has fully passed from the one condition to the other. It is curious that a writer who, like Dean Inge, has so acutely criticized the idea of inevitable progress should not have applied the same criticism to the idea of inevitable arrest of progress.

Be that as it may, the ants and the termites are still on the biological level on which, though mind has come to play a considerable part in individual and social behaviour, the evolution of the race is still entirely dominated by blind and automatic forces such as natural selection. Man, on the other hand, is on the level where evolutionary change can be brought about by changes in tradition and by conscious purpose, applied either to this tradition or to the germ-plasm of the race.

There is thus no reason to suppose that man is destined to sterilize nurses or manual workers, to breed armoured or gas-resistant soldiers, communal parents the size of whales, or an intelligentsia all head and no body. Nor is there any reason to suppose that he will settle down into a mechanized and stable condition of existence—at any rate, for the long millions of years where there will still be things for him to discover, still new enjoyments to taste, and still new changes to make by which the life of society and of the individual may be improved. By virtue of his nature, he knows that he can discover new truth, can create new works of art, can control his own destiny; and this is precisely what even the most intelligent ant or the most specialized termite entirely and for ever lacks.

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INSECTS

AN INTRODUCTION TO ENTOMOLOGY

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PREFACE

THERE have recently been quite a number of "elementary" books upon insects, and most of them follow a definite system. First there is a chapter upon Structure and Classification, and this is followed by a series of chapters in which interesting life-histories and habits are outlined. Usually, at the end, there is a chapter upon the relationships of insects and man.

I suppose all these books have many readers, but they mostly fail to show any connection between the different parts of the subject, so that the student fails to understand how intimately the three parts, structure, habit, and relationship to man, are associated, and how a thorough grounding in apparently irrelevant branches is absolutely essential for the individual who hopes to become an Economic Entomologist.

In this little volume, one part of my task has been to attempt to bridge these gaps, so that the general reader may know what the training of an entomologist means, and that this training is no more than enough to equip him for his work. I am greatly indebted to Miss K. E. Burnand for her assistance in the work of building up this book.

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INSECTS

CHAPTER I

ENTOMOLOGY IN RELATION TO THE AFFAIRS OF MAN

We have become so used to regarding ourselves as the "Lords of Creation," that we regard all other living things in the terms of their relationship towards us—they are either useful or harmful or of no importance, and unless we definitely know that a particular insect is of use to us we tend to destroy it in case it might be injurious. On the whole, I suppose this is a sound policy because, although the habits of the majority of insects are still unknown, the habits of those we do know appear to be mostly injurious to us in one way or another. But insects may be useful to us in many ways which are not too obvious at first sight.

We regard bees as useful, and most people, if asked why, would reply that they give us honey. Yet bees are much more useful to us as flower pollinators, especially since honey is no longer the important food material that it used to be before the development of sugar. We recognise the utility of the silkworm because it provides for us a useful fibre, and, although silkworms might provide us with a dainty dish, they are apparently of no other value to us. Both silk-

worms and bees have been so long cultivated by man that the true Silkworm Moth (*Bombyx mori*) is a domestic species occurring nowhere as a wild insect, and the hive bee, although occasionally becoming wild and forming its combs in hollow trees and such places, is only associated with mankind.

We cultivate a few species of bugs because we have found a use for them. For instance, the lac insect, an Indian species of bug, exudes a material which we ultimately put on the market as shellac. The cochineal insect, originally a Central American species, is cultivated because of the red colouring matter which develops in the female, and which we obtain by drying and crushing; but this insect has become of minor importance since the introduction of aniline dyes. We exploit several kinds of gall-producing insects because of the tannin which the plant develops in the galls, and which is of use in the manufacture of ink, and this practically completes the list of insects which we cultivate as being useful to us commercially.

Comparatively recently, however, we have come to recognise that we can exploit various other insects to assist us in the destruction of various species which are injurious to our crops, so that these "parasitic" forms are not only protected and encouraged, but are actually cultivated in various parts of the world and sent out to those parts where insects which they will attack are doing serious damage. We now have such a Parasite Breeding Station at Farnham Royal, Bucks, belonging to the Imperial Bureau of Entomology, for the express purpose of rearing and supplying "para-

sites " of the pests which attack cotton, sugar, etc., in the colonies.

There are, however, vast numbers of useful insects which we do not cultivate, and which many of us do not even recognise as being of any use at all. If one has the courage to turn over a rabbit or a bird, or more courage still, a cow or horse, which has been dead for some time, a loathsome, but at the same time very interesting scene presents itself — hordes of whitish maggots wriggling about in the decaying material, numerous kinds of beetles, mostly black, but many with bands of yellow or orange, and numerous other forms in insect life, all struggling to get out of sight in the mass of decay. Our first instinct is to regard them as disgusting, and yet they are being very useful to us. As soon as an animal dies, putrefying bacteria set to work to break down the organic material, and these release the gasses by which we recognise that putrefaction has set in. If such an animal were placed in an insect-proof cage the bacteria alone would, in time, reduce it to a dry odourless carcass, but the insects, warned of the presence of the corpse by their sense of smell, assemble from all quarters and feed upon the decaying material, so that it is much more quickly reduced to an innocuous condition.

Again, numerous insects inhabit the dung of animals, and here again we have useful insects. Animals feed upon organic material, and once this has been taken into the alimentary canal the digestive fluids act upon it, causing various chemical

changes, and the walls of the gut absorb those materials which are nutritive. The remainder are voided and, being organic material, are attacked by bacteria and insects, etc. These living things feed upon it, and it again undergoes digestion, absorption, and excretion, the excreted materials, however, being much less complex than previously, so that successive layers of animal or plant life break down the organic materials, which are ultimately reduced to such a simple condition that the general vegetation can make use of them as food material. It sounds unpleasant, but, after all, the whole process of life is merely building up and breaking down repeated again and again, and there are just the same materials in the world today as there were when life first appeared upon it. The dung-feeding insects, by increasing the rapidity of the breaking-down process, help to make the materials once again available for absorption by plants which are the food of many animals. I have spoken of bees as of importance in the pollination of flowers, the transference of pollen from the stamens of one flower to the pistil of another, but it is not only the hive bees which are thus useful; the bees as a group—and there are vast numbers of species—are by far the most important flower pollinators. Next to them come the flies, many of which, like the bees, seek the flowers for the sake of the nectar and become covered with the sticky pollen which they transport to other flowers. Many flies are scavengers, feeding upon decaying organic matter, so that flies, as a group, are useful, and even the house-fly and blue-bottle belong to this group

of scavengers. Butterflies and moths are also flower pollinators of about equal importance to the flies.

In August and September we suffer inconvenience and some damage from wasps which infest our houses in search of sweet food materials and which damage fruit upon the trees in the garden, and yet wasps are most useful insects. They feed their young upon insects, and one can easily watch them during the earlier part of the year hunting amongst the herbage on the banks and seizing small caterpillars or other insects which are then partially chewed up, to stop their struggles, before being carried off to the nest.

Therefore, with regard to many of these insects we find that they play two rôles; they are useful to us in one way and injurious to us in another. The wasp can scarcely be described as injurious except in connection with the damage it does to fruit on the trees, and its depradations in this direction seem to be increasing. I seem to remember a time when only ripe plums and pears were attacked, and even then it was suggested that fingers or a bruise caused the first damage, but now unripe fruit is readily attacked, even where the skin is perfectly sound. We might, therefore, place the wasp upon the suspect list, as the question will soon arise as to whether its utility as a destroyer of insects is not out-balanced by the damage it does in our gardens.

With regard to house-flies, on the other hand, we can safely say that they are more injurious than useful, though this is due to the fact that we expose our food materials instead of keeping them under fly-proof

conditions. Decaying organic matter contains bacteria, some of which can thrive inside us and cause disease. Some of the material containing them adheres to the hairs of the fly, and germs are sucked up by the insect, whose digestive fluids do not destroy them. Now, the house-fly has very catholic tastes: it feeds readily upon decaying organic materials, and it also enjoys the foods we prepare for ourselves. Moreover, it seems to enjoy feeding to such an extent that even though it has just fed to repletion, it will readily start again if a new supply of food is forthcoming. In order to make room for a further feast, it vomits up the contents of its crop. If, therefore, having fed upon the dung-hill, it comes into the house and discovers the milk or the butter exposed, it disgorges the contents of its crop on the side of the jug, or upon the butter, and feeds again. The vomit may contain disease-producing bacteria, so that, in drinking the milk or eating the butter, we become infected. The fly may also, in cleaning itself by rubbing its legs over its body and wings, deposit bacteria upon our food materials, and bacteria may also be voided with the excreta. It has been shown that the living typhoid bacillus may be passed out of the fly's body a month after the fly has absorbed it with its food.

So far I have spoken of useful insects, some of which also injuriously affect us, but there are a number of insects which, as Lords of Creation, we might describe as having no justification for their existence, as they appear to be merely injurious to us. In many parts of the world the human body-louse is

regarded by the uninitiated as a mere domestic animal, and it is not so long since the women of country districts in Britain looked upon the presence of lice as evidence of fecundity in themselves. As recently as 1919 (9)* 20 per cent. of the Board School children of Britain were lousy. Civilised people are gradually coming to regard lice as unpleasant creatures, but there is no evidence that lice, as such, do any harm to us. Unfortunately, however, they transmit diseases from one person to another, and amongst these is the dreaded typhus, which can only break out in any district where lice or bed-bug are prevalent. The insects suck up the germs of the disease in the blood of a patient suffering from it, and, on passing to another individual, they void some of the germs with their fæces. The puncture made by lice or bed-bugs becomes itchy, and the scratching to relieve this rubs in the fæces and with them the disease germs, and thus, typhus passes from person to person. During the war it was shown that trench fever and an intermittent fever were also transmitted from individual to individual through the agency of lice.

The mosquito, like the louse, is a perfectly harmless insect in itself. The female sucks blood because blood is an important food for, and aids in the development of, the eggs, although it has recently been shown that blood is not essential, as it was at one time thought to be. Unfortunately, however, the mosquito's manner of feeding is exploited by the

* The numbers in brackets refer to the bibliography on p. 78.

germs of malaria. When the mosquito drives its mouth-parts into our blood capillaries it pumps in salivary fluid, the function of which is to prevent the coagulation of the blood, and probably also to act as an external digestive. If the mosquito sucks the blood of a malarial patient it takes up some of the germs of the disease, and, if these happen to be in the right stage, they continue their development in the mosquito, passing through the walls of the gut, and, ultimately, after about eleven days, they reach the salivary glands. During all this time, the mosquito can continue to feed upon people without causing them any damage other than the irritation at the puncture, but once the malarial germ has reached the stage in the salivary glands, the mosquito, in pumping out saliva during feeding, pumps out the germs also, and thus infects the blood of another individual. Here again, then, another person is the cause of our getting the disease, the insect being the vector or carrier from one to the other; but whereas in the case of the house-fly the insect was of no importance to the disease germ except as a carrier, in the case of the mosquito the insect is a necessary host for the disease germ to enable it to complete its life cycle.

These, then, are examples of insects harmless in themselves which unfortunately transmit disease germs between man and man, and there are a large number of this type, but there are also diseases directly due to the attacks of insects. The common flea is only dangerous as a carrier of the germs of plague, but the "Jigger" or Chigoe flea burrows into the

flesh, which may suppurate and cause bad wounds. Otherwise most of the directly injurious insects are flies, and where fly maggots invade the human body, medical men speak of Myiasis. It is a curious fact that, although fly maggots breathe air like other insects, some of them survive for long periods inside the animal body. In some cases, as for instance where the fly lays its eggs in the nostrils or in an open wound, the maggots may retain contact with the outside air, but in cases where the alimentary canal is invaded, as sometimes happens, it is difficult to understand how the insects obtain the necessary oxygen. Excepting the "Jigger," there seem to be few insects which burrow directly through the human skin, but there is one fly, known as Dermatobia, which adopts special means of getting its larvæ into the body. For a long time no one could discover how the larvæ of Dermatobia got into the body, and various suggestions were made. One of these was that the fly laid its eggs upon washing hung out to dry, and the eggs on the underclothes hatched when in contact with the body and the larvæ then bored their way in. Now it is known that the Dermatobia lays a neat little parcel of eggs upon the underside of the abdomen of a small blood-sucking mosquito, Janthinosoma, and that while this mosquito is sucking human blood, having pierced the skin by means of its mouth-parts, the Dermatobia eggs hatch, and the larvæ make for the puncture caused by the mosquito and thus enter through the skin.

Domestic animals suffer from insects in the same

ways as human beings—that is, in some cases the insect is merely a carrier of disease germs, while in others the insect itself is the cause of the trouble. Our cattle in Britain suffer from the attacks of the Warble fly (*Hypoderma*), which lays its eggs amongst the hairs, usually upon the legs. The maggots hatch out and themselves penetrate the skin and move through the body until they reach the back, by which time they are getting fairly large. Here they break through the skin and bring their spiracles or breathing pores to the opening, and these wounds may suppurate and cause considerable suffering to the animal. Apart from this, however, the damage done to the skin is such that the value of the hide is greatly reduced and the annual loss in value in our islands runs into some millions of pounds. The bot-fly of the horse (*Gastrophilus*) lays its eggs, like the *Hypoderma*, on the hairs, but in this case the horse licks itself and, if its tongue comes into contact with the eggs, these hatch and the maggots stick to the tongue and thus pass into the mouth. They reach the stomach, where they hold on to the walls by means of their mouth-hooks, and there they feed. Now, there is not a ready supply of air in the horse's stomach, all there is being in the form of bubbles swallowed by the horse while feeding. These maggots are, therefore, specially adapted to these conditions as they possess masses of cells containing hæmoglobin, the red colouring matter of human blood, which has a great affinity for oxygen. The bubbles of gas in the horse's stomach are caught in a vestibule at the posterior end of the fly larva, and

the oxygen is extracted from the bubbles by means of the hæmoglobin. The full-grown larvæ let go their hold on the walls of the stomach and are passed out with the excreta, and shortly afterwards they hatch out as flies. The horse naturally gets on better without these internal parasites, which, if numerous, may cause serious trouble and even death.

These are examples of the numerous insects which injuriously affect us by damaging our domestic animals, but we are also very seriously affected by many species of vegetarian insects, which attack our crops and levy a very heavy toll upon us; in fact, there are few commercial undertakings connected with plants where we do not suffer heavy losses from insect damage. In the tropics, almost all woodwork used in the construction of houses is liable to attack from termites, or so-called "White Ants." These insects shun the light, and under normal conditions are not seen in a house, the first warning of their presence being when a chair or table collapses or when one puts one's finger through a rafter or a door-post. The exposed surface is left intact and the inner parts are eaten away. Again, there are many wood-boring beetles which do considerable damage to lumber in the yards, and after it has been used in the construction of buildings and very many of our older English churches, with their beautiful oak work, are having to be repaired at the present time because of the damage done by a wood-boring beetle. Soft woods are attacked by other species, and many of us have, perhaps, suffered from the collapse of a wicker-chair

owing to the work of a small beetle in the willow wands.

As Lords of Creation we may ask, What is the use of these wood-eating insects? I have even been told by a pious lady that they have been sent into the world to humble us. As a fact, these insects are useful insects, and, if we may continue in the strain of the pious lady, they have been sent into the world to break down wood-fibre when the plant is either sickly or actually dead. In other words, these insects are scavengers, like the dung and the carrion-feeders. Unfortunately, we kill the trees for our own uses, and, so far, we have discovered no means by which we can teach these useful insects to discriminate between dead wood lying in the forest and wood we are making use of.

If we are going to justify the insects which cause us millions of pounds' worth of damage by destroying our timber, we might put forward a good case for any other insect which we regard as injurious. So far as the world is concerned we might regard the disease carriers as useful in that they reduce the numbers of human beings, and thus postpone the day when birth control will be a *sine quâ non*. The insects which attack our crops are really attempting to assist Nature by keeping down excessive numbers of individuals of a particular species. But in adopting this attitude we have ceased to be Lords of Creation, and have adopted what might be the views of the Almighty. Self-preservation being strong within us, we shall continue to take the line that we must adopt all measures to

"protect ourselves," which means that we must endeavour to destroy all those insects which interfere with our own schemes. If this is the wrong view to take, then there is little doubt that before very long insects will dominate us. The mosquito has, according to the views of well-known authorities, retarded civilisation, and even destroyed it more than once. The ancient civilisation of Greece was probably destroyed by malaria, and wave after wave of civilisation in Africa has been dissipated by the same dread disease (3). Now we are learning how to control the mosquito, and many parts of the world which were uninhabitable a few decades ago, are now at least tolerably healthy. We are learning now to overcome some of the insects which attack our crops, and we shall, no doubt, gradually reduce the losses. Everyone at once recognises that the reduction of disease is a good thing; but many people may say: So long as we can grow enough of a crop to supply us, what does it matter if insects destroy the rest? If we have to grow twice as much of any crop as we actually require because insects destroy half of it, it means double the labour in cropping and it means double the expense. Someone has to pay for this, and the losses are mostly passed on to the consumer, the ultimate buyer of the prepared product. If, therefore, we can reduce the losses, the price to the consumer will come down, but as we are now straying into questions of political economy, we can leave this subject, although some of the points raised in this chapter will be expanded as we proceed.

CHAPTER II

THE STUDY OF STRUCTURE AND FUNCTION

It is a common saying that every organism is adapted to its environment, which means that the structure and habits of every animal and plant are such as to fit it to occupy the place in which it lives, the place it lives in being its environment. But this environment is highly complex; it is made up of the climatic conditions, amount of sunshine, rainfall, range of temperature, and so on; the edaphic conditions or nature of, and moisture content of, the soil, and the organic conditions—that is, the living animals and plants occupying the same place. Consequently every species not only has to be able to withstand the extremes of climatic and soil conditions, but has also to hold its own, obtain its food supplies, and reproduce its kind amongst all the other living things, many of which are directly competing with it for food and place, and all of which are in some way affecting it directly or indirectly.

To take a broad example : We can group the animals living in any area into carnivorous or flesh-eaters and herbivorous or plant-eaters. The latter depend upon the vegetation for their food, while the former depend upon the vegetarians. The plants are kept in check because they are eaten, but they are protected from extinction because the carnivorous animals are keep-

ing in check the vegetarians, and thus there is a balance between the three groups. If anything happens to cause a decrease in the vegetation, both groups of animals are affected. If the vegetarians decrease, the vegetation increases and the carnivores are reduced by partial starvation. Of course the interrelationships are much more complex than the above example indicates, but it is often possible to pick out of the general tangle a series of relationships which has been called a biological chain. Darwin gave an excellent example of such a chain in the *Origin of Species* (7).

Leaving out the intermediate links in the chain, it may be said that the amount of clover seed in any district depends upon the number of cats, which sounds ridiculous. Clover is pollinated by humble bees. "The number of humble bees in any district depends in a great measure on the number of field mice, which destroy their combs and nests. . . . Now the number of mice is largely dependent, as everyone knows, on the number of cats. . . . Hence it is quite credible that the presence of a feline animal in large numbers in a district might determine, through the intervention first of mice and then of bees, the frequency of certain flowers in the district." This chain has since been increased by the addition of another link, as it has been pointed out that old maids, more frequently than other people, keep cats, so that it may be said that the amount of clover seed in any district depends upon the number of old maids.

It is obvious that everything which affects any one

of the links in such a chain affects the whole chain, and, as such a chain is entangled with other chains in the same locality, Nature strikes a balance between all the living organisms, by which, unless something out of the way occurs to upset it, the numbers of individuals of each species remain more or less constant or wax and wane very slowly. But various things do upset the balance. Excessive rain may flood a district and destroy most of the living things, or a hurricane may lay out large areas of woodland, making the district quite unsuitable for the animals which previously lived in the shade of the trees, but more suitable for other forms which will then invade the area and replace the original occupiers.

Man is perpetually interfering with the balance of Nature. He drains marshes and irrigates dry land. He cuts down forests and thereby not only affects the shade-loving animals and plants which sheltered beneath the trees but also affects the climatic conditions, since forest areas are always more moist than open ground and enjoy additional rainfall. In Nature, vegetation is mixed, so that large areas of one species of plant to the exclusion of all others are uncommon. Man deliberately plants large areas of pure forest or of other commercial plants, and all his arboricultural and agricultural methods are at variance with natural conditions.

Nature is perpetually attempting to balance. Thus we see that clearings in tropical forests grow up again unless man continues to keep them clear. According to the amount of man's interference the balance may

be quickly restored, so that after a short time nothing remains to indicate the temporary disturbance, or, as is more usual, the balance is restored after a time, but the environment is permanently changed.

The mongoose was introduced into Jamaica to keep down the rats which, originally introduced from ships, were in excessive numbers in the sugar-cane fields. The mongoose reduced the rats in the fields, partly by destroying them and partly by causing them to migrate to the houses. This led the mongoose to look elsewhere for its food supplies, and it attacked the snakes, lizards, and any birds it could catch. But, with the reduction of the reptiles and birds, the insects, which had been kept down by them, began to increase in numbers, as did also the ticks, which became very abundant. Apparently, however, the increase in the ticks adversely affected the mongoose, which consequently became less abundant, and once more lizards and birds began to increase and the balance of Nature was restored, not in its original form, but adjusted to include the mongoose.

The mongoose was also introduced into St Lucia with the object of reducing the rats, and there also the consequences were similar. A mole-cricket (*Scapteriscus didactylus*), which feeds on the roots of various plants, became especially abundant because of the reduction or extermination of a ground lizard, and efforts have been made to re-establish this useful reptile with a view to reducing the ravages of the mole-cricket.

There are certain flies, usually known as blow-flies,

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whose primary object in life is to act as scavengers. They lay their eggs in decaying organic matter and their larvæ or maggots eat up the material. Some of these flies lay their eggs in the soiled wool of sheep, especially round the anus, and the maggots have developed the habit of destroying the wool and even eating into the flesh of the sheep and setting up blood poisoning. Large losses result to the farmers every year in the British Islands and other countries from what are called "Sheep Maggot Flies," and, although it sounds absurd, the introduction of rabbits into Australia caused a tremendous increase in "blown wool" in that country. The rabbit was not a native of Australia, but the early settlers had some sent out from the home country. The rabbit found that Australia was the country for which it had always been looking, and it increased and multiplied to such an extent that, in a very short time, it became a serious pest, eating up everything which the settlers planted. Urgent requests were then sent home for something to control it, and a number of weasels and stoats, chiefly collected in East Anglia, were sent out. These animals apparently were unable to cope with the situation, but their removal from this country seems to have been followed by a temporary increase in the number of rats.

As they failed to do the work for which they were transported, other measures had to be adopted and a price was set upon the head of the rabbit. This resulted in vast numbers being killed, and their dead bodies were allowed to lie and decay. The scavenging

blow-flies came to assist in the work of disintegration, and, owing to the abundance of food material, they increased and multiplied to an enormous extent. The rabbits were gradually reduced in numbers and the blow-flies found themselves out of work, and whereas previously only two species had interfered with sheep, now another six have developed the habit and the losses to Australian farmers are very serious. From this last example we see, that, although the blow-flies were originally scavengers, they re-adapted themselves under the stress of circumstances, and this leads us to consider the meaning of adaptation. We have already seen that an organism is adapted to its environment, and, since the environment is constantly varying, any particular species must either be sufficiently plastic to withstand the variations or it will be eliminated by natural selection. Plasticity naturally varies with different species, and many are quite obviously very plastic. For instance, many insects are polyphagous—that is, are capable of eating a number of different kinds of plants and can actually be found on the different plants. They can be transferred from one kind of plant to another, and will continue to feed without any difficulty.

On the other hand, there are many insects which apparently are monophagous, always being found upon one kind of plant. To all appearance, therefore, these species are non-plastic, so far as food is concerned, but, under stress of circumstances, it is found that they can thrive perfectly well upon some quite different food plant. In Montana, U.S.A., in 1909 certain owners

decided upon cleaning up their orchards, and in so doing they destroyed quantities of a common weed, *Artemisia tridentata*. This was the normal food plant of a beetle, *Cercopeus artemisiæ*, which, in the absence of the Artemisia, attacked the cherry-trees and did considerable damage. In the vineyards in a certain district in France it was discovered that the advent of a small bug (*Nysius senecionis*) on the vines coincided with the ploughing in of a weed pest (*Diplotaxis erucöides*), which is its normal food plant and which it definitely preferred to the vines.

Cameron (5), in 1914, showed that a small fly, the Belladonna Leafminer (*Pegomyia hyoscyami*), attacks henbane (*Hyoscyamus niger*), but, in the absence of this food plant, belladonna (*Atropa belladonna*) is readily eaten. The caterpillars of the Nun Moth (*Lymantria monacha*) feed upon spruce leaves on the Continent and often do such damage by defoliation that the trees are killed, unless active measures are taken to destroy the pests. In Britain, the caterpillars are mostly found upon oak, birch, and such trees, and do but little damage to conifers.

These latter, then, are examples of what we might call "potential plasticity," which only becomes evident under certain conditions, and there are other examples where, so far as we can see, the plasticity exists but is never used at all. For instance, besides the wasps, which live a social life, there are a number of solitary forms in which each female lays up a store of food in a series or group of cells, laying one egg in each cell. The food is for the wasp grub which hatches from

the egg, and the mother stores up sufficient to enable the grub to grow to full size and to change into a pupa. Each species of solitary wasp stores up a particular kind of food for its offspring. One will store caterpillars, another bees, another beetles, another beetle larvæ, another spiders, and so on: but the one which stores caterpillars will never change over to flies or anything else. Yet experiment shows that the wasp grub, which normally feeds upon caterpillars, can thrive equally well, say, on beetle larvæ, and yet apparently this plasticity is of no use whatever to the species.

Here is an example of lack of plasticity in feeding powers. There is a solitary wasp (*Sapyga 5-lineata*) which lays its eggs in the cell of the small Blue Osmia Bee (*Osmia cærulescens*). The egg of the parasite hatches out quickly and the wasp grub feeds upon either the egg or the young grub of the Osmia. Having finished this it changes its diet, feeding upon the mass of honey and pollen which the mother bee had laid up as food for its own offspring.

A closely related bee, the Red Osmia (*Osmia rufa*), is seldom attacked by the Sapyga, although from time to time the parasite lays its egg in the cell of this bee. Apparently the only thing which prevents the Sapyga grub from growing up in the Red Osmia cell is that the honey is scarce compared with the pollen, that is, the food material is too dry, because experiment shows that the Sapyga grub can grow up quite well on the Red Osmia food store if a little honey or treacle is mixed with the latter. As we shall see in a later

chapter the adaptation between insects and flowers is sometimes so fine that a species of plant may be entirely dependent upon some particular kind of insect for its pollination, which, of course, means that the plant is limited as to it geographical range by the distribution of the insect.

Animals and plants living in countries where there are extremes of temperature in winter and summer are adapted to these conditions, sometimes by the amount of fat or the thickness of fur in the different seasons and sometimes by going to sleep during the winter (hibernation), or during the summer (æstivation). Such climatic changes are gradual, so that the organism gets time to adapt itself to the change, but some organisms are capable of rapidly adapting themselves to changed conditions. For instance, some estuarine forms withstand equally well salt, brackish, and fresh water.

There is a small beetle (*Octhebius lejolisii*) which occurs in rock pools on the coasts of Western Europe and endures remarkable and rapid changes of environment. After a storm the rock pools are filled with pure sea water. If a spell of calm and dry weather ensues the water is slowly evaporated by the heat of the sun and the salt concentration increases until the pools dry up. Heavy rain will reduce the salinity until the water may become almost fresh. During the middle of the day the temperature of the pools rises very high, while at night the temperature quickly falls. Under these changing conditions the little beetle lays its eggs, and its larvæ grow to maturity.

The above are just a few random examples of the plasticity of the organism—that is, of its powers to adapt itself to its environment—and now it is time we inquired as to what is meant by the word "Adaptation." Adaptation is a matter of habit in relation to structure. Sometimes from a study of structure, including form and colouring, we may guess at the habits, but only to a limited extent. We may take it as an axiom that every structure is either of use to the organism possessing it or is the remains of something which has been of use to the ancestors. Knowing that bees visit flowers, it is fairly safe to foretell when a new bee with lengthened mouth-parts is discovered that it searches for nectar chiefly in long tubular flowers. Knowing the ordinary habits of ground beetles, we may guess with some expectation of being right that a flattened species lives either under bark or in some circumstances in which its flatness is of use to it; the real point being that structure, form, or colouring can be of no use to an organism unless the habits are in conformity with it: in other words, habits are adapted to the structure of the organisms. Of course, in many cases, habits are the direct outcome of the structure, but there are other cases in which there is no apparent connection between the one and the other, and yet the structure would be quite useless without the habit. For instance, many insects are so shaped and coloured that they harmonise with their surroundings and are very difficult to see. There are brown caterpillars shaped and marked to resemble twigs, and there are stick and leaf insects which

so closely resemble twigs and foliage that it is almost impossible to discover them. There are moths which look like the bark of trees, and others which look like patches of lichen, and so on. In all these cases, however, the value of the appearance depends entirely upon the insect remaining motionless during the daytime. Sticks or leaves, bits of bark, or of lichen moving about would attract the attention of passing birds and animals, and the cryptic appearance would be quite useless. Consequently, all cryptically-shaped-and-coloured insects, and other animals, are active at night and passive during the day.

If a number of butterflies of different kinds are offered to some young and inexperienced insectivorous bird or animal, it will be found that, for the most part, the brightly-coloured ones will be rejected with obvious signs of dislike while the quietly-coloured ones will be eaten, from which we may draw the obvious conclusion that the brightly-coloured ones are distasteful. If we now have an opportunity of observing some of these butterflies alive and under natural conditions, certain peculiarities of habits will be easily observed. The brightly-coloured ones fly lazily and slowly, are easy to catch in the net, and when they rest they spread out their wings as if to display their gaudy colours. The dull-coloured butterflies have a rapid zigzag flight, are difficult to catch in the net because of their dodgy flight, and when they rest they close their wings vertically over their backs, exposing only the undersides, which are often so coloured as to harmonise with the surroundings. The

brightly-coloured kinds are advertising their presence, and insectivorous birds, having bought their experience by catching a few, pass the others by. The safety of these forms lies in making themselves as conspicuous as possible so that the birds may not mistake them for something dainty. The safety of the palatable forms depends upon their making themselves difficult to catch and difficult to find when at rest, so that the difference in habit between the two types is associated with difference in colouring.

But there are relations of the quietly-coloured butterflies which have taken on the bright colouring of the unpalatable forms, and, just as they have developed the colouring, so also have they developed the habits. They mimic the unpalatable forms in colouring and habit, and are therefore protected because the birds do not distinguish them from their models. But this is not the end of the story.

Their success depends not only upon their colouring and habits, but also upon the fact that they are scarcer than their models, and it is easy to see why. If the young bird, learning by experience what is edible and what is not, finds that a few of the brightly-coloured butterflies are good but that most of them are nasty, it makes up its mind not to waste time on them; but if it happened to find that most of them were good and only a few nasty, it would continue to feed upon them, rejecting now and again the unpleasant ones. Thus the mimic would not only lose the protection it gains by its mimicry, but the model would quickly cease to exist. Here, then, we see a

further very delicate adaptation. The mimic must always be less abundant than the model or it destroys itself.

But what has all this got to do with economic entomology? What is the importance of a knowledge of structure and habit to the man who has only to destroy insect pests? The scattering of Keating's powder, the "swatting" of wasps, or the putting up of fly-papers does not require any previous training, and, to many, these include almost everything which comes under the heading of economic entomology. If an insect is destroying a crop, the layman says, "Kill it." But how? It would be very expensive to go over a field with Keating's or with a swatter. The layman probably says, "Hasn't anybody else had the same trouble, and, if so, what did he do?" Here we have our first scientific problem. If we are going to find out whether someone else has had the same trouble we must be able to identify the insect, and to this end we must examine its structure in order to determine to which group it belongs and where it comes within that group, and we are thus undertaking research in "systematic" entomology. The layman may retort, "Get it named at the Natural History Museum"; but that does not get rid of the fact that the study of systematic entomology is necessary before we can name our insect.

Having discovered the name of the pest, we may be able to find a description of its life-history and habits, if they are known; if not, we must set about studying them. "What for?" says the layman. Be-

cause the insect may lay itself open to attack at some stage, or at some time of the year, or even at some time of the day, and be otherwise difficult to destroy. If, for instance, we discover that a moth lays its eggs in batches which are easy to find, or that the caterpillars readily expose themselves to attack, it is waste of time to try and destroy the scattered moths. Why waste the day trying to destroy beetles upon fruit bushes if a study of the habits reveals the fact that they are much more readily found at night? Thus a careful study of habits provides the decision as to the method to be used for overcoming the pest.

But the layman will probably counter this statement by saying, "Well, by this time the habits of most of the ordinary pests are well known, so that there is no need to spend any more time on that part of the subject." From what has been said earlier in this chapter, it is obvious that the habits of insects often vary from country to country, and even from district to district, and very slight variations may make a great difference as to the method or time of attack. For instance, the eggs may hatch earlier in one part of the country so that the whole life-cycle will be in advance in one place of what it is in another. If the egg stage is the one which is most easily attacked, it may be necessary to operate a week or more earlier in one place than in another; otherwise the work will be a useless waste of time, and, of course, where it is on the large scale, a waste of money also. In connection with this variation from one district to another several papers have been written, notably by

A. D. Hopkins (12, 13, and see 6), of the United States, who has worked out what he calls the "Bioclimatic Law" for an area of his country from which he shows that if an insect normally appears, say, in the adult stage, at a particular date in one district, it will be so much later in another district, and so much later in another. As has already been shown earlier in this chapter, the fact that we know the life-history of a species in any one country is not justification for assuming that it is the same in another country, and we need only remember the different feeding habits of the Nun Moth caterpillar on the Continent of Europe and in Great Britain. The common Slave-making Ant (*Formica sanguinea*) varies its habits in different places. Whereas in one district all the nests will be found to contain numerous slaves, in another the Sanguinea makes no slaves, and does all the work itself.

Closely related species frequently differ remarkably in habits, so that a knowledge of the life-history of one is useless as an indication of that of another. The Large White or Cabbage Butterfly (*Pieris brassicæ*) lays its dark yellow eggs in batches of twenty or more, and the caterpillars, when they emerge, remain together and continue together until they are full grown. They are conspicuously coloured in black and yellow, and are usually to be found upon the upper side of the leaves of the food plant. The Small White Butterfly (*Pieris rapæ*) lays its pale yellow eggs singly, and its caterpillars, which are of the same green colour as the food plant, are solitary, and spend the daytime lying motionless, usually on the underside of the

leaves. A small bug, known as the Apple-Sucker (*Psylla mali*), lays its minute yellow eggs round the apple buds in the autumn and the young hatch from them in the following spring. A closely related species, not too easily distinguished, known as the Pear Psylla (*Psylla pyri*) winters in the adult stage, sheltering in crevices in the bark and under rubbish during the cold weather, and lays its eggs in the spring. A method of destroying the Apple Psylla is to paint the twigs with lime or some other chemical wash during the winter and thus to destroy the eggs, a method of treatment which would obviously be useless against the Pear Psylla.

Several species of aphis or "green-fly" attack the apple. One of these, the Green Apple Aphis (*Aphis pomi*), winters in the egg stage on the twigs and round the fruit-spurs. When the leaf buds are opening in the spring these eggs hatch, and the young aphides enter the opening buds and suck the sap of the young leaves. In two or three weeks these individuals have grown into wingless females, which soon produce a brood of young aphides, mostly wingless like their mother, though a few develop wings as they grow. These young are full grown in another two or three weeks, and they disperse about the tree, the winged individuals flying to other apple-trees in the neighbourhood. These again give rise to another generation, and this goes on all through the summer, six or eight broods being produced by early autumn. At this period males appear for the first time, and mate with special females, these latter seeking out apple twigs,

and each laying from two to six eggs, thus completing the annual cycle, the eggs lying dormant through the winter.

It would seem logical to say, "now we know the life-history of this aphis, that of any other aphis, especially on the apple, should be much the same"; but a study of other species shows that this is not the case. The Rosy Apple Aphis (*Aphis sorbi*) commences active life in the spring in the same way as the other and, until about June, its habits are similar, but at that time winged females appear and fly away, and in a very short time every individual has disappeared from the apple. For a long time it was not known what happened to these winged individuals, but it was ultimately discovered that they fly to a small weed known as plantain or rib-grass, and there continue the life-cycle of the species. In the autumn winged females are again produced, and these return to the apple, where they give birth to females and males, the former laying the eggs which lie dormant through the winter.

The Woolly Aphis, or, as it is sometimes called, "American blight" (*Eriosoma lanigera*), like the Rosy Apple Aphis, normally relies upon two host plants, the apple and the elm, for the completion of its life-cycle, but in the autumn it gives rise to a generation which goes down to the roots of the apple and there survives; individuals coming up to the trunk and twigs in the spring and re-establishing the attack on the subærial parts of the tree. Thus they intensify the infestation which would otherwise depend only

upon the arrival of winged individuals from the elm about June, or, rarely, upon winter eggs laid in the cracks of the bark of the apple.

Here, then, are three apple species of "green-fly," and it is quite clear that a minute knowledge of the life-history of one of them is of little use in devising methods of attacking either of the others. Perhaps enough has been said in this chapter to convince the layman of the intimate connection between a knowledge of the structure and habits of insects and the destruction of insect pests, or, in other words, that the successful carrying out of this work depends upon that knowledge.

Governments and laymen in this country have been slow to realise that the successful application of science requires a fundamental knowledge of that science. But we have now become wiser, and our Committee of Scientific and Industrial Research and other committees and corporations provide funds for carrying out researches in pure science, regardless of whether or not the ultimate object of the work is economic, on the principle that sooner or later such work will directly or indirectly become useful. More recently the Empire Marketing Board has come into existence, and it has been quick to show by its wise distribution of the funds provided for it that it recognises the importance of the study of pure science in the successful exploitation of the agricultural products of the British Empire.

CHAPTER III

INSECT PARASITES AND PREDATORS

The term "parasite" literally means one who takes food with another, and we might, therefore, justifiably so describe the friend whom we have asked to lunch. So far as insects are concerned, there are very few such parasites, and most of these occur in the wasp and bee families, where the solitary wasps and bees construct cells, lay their eggs in them, and store them with food for their future offspring. The parasite members of these families lay their eggs in these cells and the parasite grub eats up part or all of the food stored in the cell and, sooner or later, the egg or the developing grub of the host. But the term is used in a much wider sense. There are so-called ecto-parasites and endo-parasites, which live and grow upon the outside or within their host, and if we restricted the name "parasite" to these we might define an insect parasite as one which passes at least part of its early life upon or within an animal (as opposed to a plant) host, to the serious detriment of that host.

The definition would include all the highly specialised insect parasites other than those already mentioned, which might be described as predators, and all such highly specialised parasites are confined to three of the main groups or Orders of insects, the Beetles, the Flies, and the Bees and Wasps. But various insects with very different habits are described as

parasites. Lice spend the whole of their lives associated with warm-blooded animals, not only for the sake of the blood which they suck, but also for the sake of the warmth. They would almost come within our definition, except for the fact that they do not destroy or seriously injure their hosts. Fleas are in a different category. They only occur on animals in their adult stage, their eggs and larvæ being found in dust and other débris such as occurs in empty houses, chicken-runs, and such places. If fleas are parasites, then mosquitoes and other blood-sucking flies are also parasites, since their relations to their hosts are similar. The Bird- or Biting-Lice (*Mallophaga*) are described as parasites, and yet they only feed upon the débris of feathers and fur and flakes from the skin of birds and other animals, so that they are really scavengers. It is quite clear that a definition to include all these insects of very different habits will be a very broad one. If we define as a parasite an insect which lives at the expense of its host, then every predaceous insect comes within the category, and it is rather interesting to note that in the various "Parasite-breeding" Stations, in different countries, a large part of the work consists in breeding certain types of predators. These are insects which are restricted in their diet to a limited number of types, and in order to distinguish them from insects which will eat numerous other types of insect food, they are known as "special predators" as opposed to "general predators."

For the purpose of this chapter, therefore, we will confine our attention to those insects which come

within our limited definition, which includes ecto- and endo-parasites, and also to these special predators, our definition of the latter, as given a few lines above, being such as will include the bee and wasp parasites mentioned in the first paragraph of this chapter. And first with regard to parasitism. It is quite certain that it has arisen independently in the three large groups in which it occurs, and there is little doubt but that it has arisen more than once within a group. Moreover, it has probably originated in several different ways. If we examine the parasitic or cuckoo-bees, we find the curious fact that most of them bear some resemblance to the species which they impose upon. The hard-working female solitary bee, having selected a site for her cell or cells, commences work by bringing in material, it may be pellets of earth or clay, as in some species, or chewed-up plant tissue as in others, and gradually builds up a wall. The bee then becomes a forager, gathering nectar from flowers and converting it into honey in her crop, and pollen which adheres to her body. She brings this material back to the cell, disgorges her honey, and unloads her pollen, mixing up the two to form a paste. A number of journeys, it may be ten or fifteen, are required in order to complete the store of food material in one cell and, this having been done, the bee then lays an egg upon the pollen paste. Then once more she becomes a builder and closes up the cell. The cuckoo-bee, always searching about for her host, discovers a cell during its preparation and waits her time until either the foraging is completed or the egg has been laid and, selecting a

time when the owner of the cell is out, she slips in and rapidly deposits a single egg on the floor near the pollen paste. The host bee returns and either does not recognise the presence of the strange egg or does not realise its significance and, when she completes the closing of her cell, the two eggs, her own and that of the parasite, are left with a supply of food sufficient only for one. The parasitic egg usually hatches first and the young grub either commences to feed upon the pollen paste or at once attacks the egg of the host; at any rate the cell is ultimately emptied of its food and only one grub, that of the parasite, survives to pupate.

Now the first thought upon this matter of parasitism is that the parasite saves itself the trouble of building and stocking cells for itself by laying its eggs in the cells of other bees, and we may take it that this kind of parasitism actually arose through individuals getting this labour-saving idea. Each species of solitary bee builds its own type of cell and stores it with its own type of pollen paste, the latter being sometimes very moist because it consists of much honey in proportion to the pollen and sometimes very dry when the pollen is in excess. If an individual bee gets the idea of saving itself trouble it would seem natural that, for the sake of the welfare of its offspring, it would lay its egg in a sister's cell rather than in that of a strange species. Moreover, it would perhaps understand the habits of its sisters and would instinctively know, as they know, the different stages in the process.

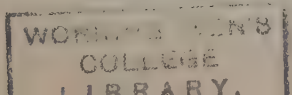
That this was probably the origin of the cuckoo-

bees is rather borne out by the fact mentioned earlier that many of them somewhat closely resemble their hosts in appearance. We may take it that this type of parasitism has been a paying proposition, and that many individuals in a species have followed the fashion until the idea has become so popular that there have not been left enough working sisters to use as hosts. This has led the parasites to attack another species, probably a closely related one, and the evolution has been so comparatively recent that many of the species of cuckoo-bee are still at work upon their near relations; hence the resemblance in appearance. There are actually some species with regard to which it is not yet certain whether or not they are parasitic, and it is possible that these are species in which parasitism has only just commenced; in which case, of course, evidence by different observers is likely to be conflicting (20).

But although these are called "Parasitic or Cuckoo-bees," there is a great group of forms in the Bee and Wasp Order, or Hymenoptera, known as the *Hymenoptera Parasitica,* in which the majority of the forms are ecto- or endo-parasites, and they have developed parasitism into a fine art. If the origin in this group was due to laziness, the parasites seem to have got to love their profession and have spared no pains to elaborate it. Although the majority of this group are parasites, included with them is a family known as *Cynipidæ* or Gall-flies, which would be better called "Gall-wasps," as there are no gall-producers amongst the true flies.

The Cynipids lay their eggs singly in the tissues of plants and the irritation caused to the plant tissues, either by a secretion produced by the mother at the time she inserts her egg or by the young grub after it emerges from the embedded egg, causes the plant tissues to proliferate into a gall. The same species of gall-wasp always causes the plant tissues to develop into a definite type of gall which can always be associated with that particular gall-wasp. The grub of the gall-wasp becomes embedded in the midst of the gall tissue upon which it feeds and, when it is full grown, it turns into a pupa within the remains of the gall, from which the adult later escapes by biting its way out.

Here, then, we have a type of vegetarian insect which is included within the group of the *Hymenoptera Parasitica* because its structure clearly indicates that it is closely related to the parasitic forms, and it seems reasonable to believe that these latter, now entirely dependent upon insects for their food, have originated from vegetarian ancestors. In the galls of many of these Cynipids there are frequently to be found a number of grubs feeding, like the owner of the gall, upon the proliferated plant tissues. These belong to related species which, like the cuckoo-bees, have developed the habit of saving themselves trouble by laying their eggs in ready-made homes. They are mere guests or "inquilines," and are true parasites in the sense that they share the food with the owner, but otherwise they do it no harm. Besides these guests there are yet other grubs, closely related to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them, which are carnivorous and, instead of feeding upon the gall tissues, feed upon the occupants of those tissues, and it seems reasonable to regard these as having originated from the inquilines by a change of diet. Now these are not parasites according to our definition but are predators, the eggs being laid in proximity to, but not upon, the host species, and the grubs grazing upon the host grubs just as any other predatory insect, far removed from any suggestion of parasitism, feeds upon its prey. And yet it seems possible that these predators formed the intermediate link between those forms which live upon a vegetable diet and the true ecto- and endo-parasites (11). After all, the difference between a predator and a parasite is really very small.

Just as in the case of the solitary bees, the solitary wasps, of which there are a number of families, each containing a number of species, store up in cells food material for their offspring; but whereas the bees store pollen and honey the wasps store insect or spider material, each kind storing a certain definite type of food as already mentioned. The simplest of these solitary wasps, a group known as the "Scoliid wasps," construct no cell, but hunt for the larval food, which consists of the juicy grubs of certain beetles. In order to find these, the mother wasps burrow in the soil, as the white grubs feed upon the roots of plants. Having found such a beetle grub, the mother Scoliid stings it in order to paralyse it and then lays a single egg upon it. This egg ultimately hatches out and the Scoliid grub feeds upon the living beetle larva and

becomes full grown about the time it has exhausted its food supply.

The structure of the Scoliid, when compared with that of other solitary wasps, is more simple and therefore we regard it as a more primitive type. We are justified in believing that insects of more primitive types will have more primitive habits, and we find therefore that these primitive wasps were ecto-parasites and that, as the wasps evolved, they elaborated their parasitism. Instead of merely finding the host and laying an egg upon it, they have developed the habit of constructing a special cell and bringing the host to it. But notice how very near this primitive Scoliid is to a simple predator. If, instead of laying its egg upon the host, it laid it in its neighbourhood, and if the young grub on hatching had to seek for its food, the Scoliid would be a typical predator, so that the difference between a predator and an ecto-parasite is almost negligible. We find amongst the *Hymenoptera Parasitica* quite a number of forms in which the egg is not laid upon the host, the young parasite grub having to find its way, sometimes a very strenuous way, to the food material. In some cases this may be a pre-parasite phase, whereas in others it seems as if it were a modification of the parasite habit.

Having then established the exceedingly close relationship between predator and parasite we can argue that the former gave rise to the latter, because of the number of more primitive predatory insects and the complete absence of true parasites in these more primitive groups. And yet if we compare vegetarian insects

with carnivorous ones we find that the majority lay their eggs upon or in the material which will later form the food supply of the young, so that the development of the carnivorous habit brought with it the necessity of the young insect hunting for its prey, whereas the development of the parasite restored the position in which the mother placed her egg so that the young, when it hatched, could feed at once. We saw in the case of the cuckoo-bees that, according to Wheeler's theory of their origin, they were destroying their hosts, but, from an economic point of view, this is a bad policy, and as a fact the average parasite does not work upon this principle. It usually avoids committing suicide, either by having more than one host, so that if one fails there is some other to rely upon, or else its abundance is such that it does not seriously affect the abundance of its host. The former type of parasite is described as polyphagous as opposed to the latter which is monophagous, and we may regard this latter as more modern because it means a higher degree of specialisation and adaptation between parasite and host. And the relationship is such that if the host becomes more abundant the parasite also increases in numbers, and when the host numbers diminish, the parasite numbers do the same.

If we determine from year to year the abundance of the host, we can trace out a curve showing how the species waxes and wanes, and a curve drawn to show the history of the parasite will be found to show the same form, but the maxima and minima will always be later than those of the host. That is, the host

reaches a maximum abundance and begins to decrease, and not until the host has passed its maximum does the parasite reach the apex of its curve. We can deduce from this, that, but for the parasite, the host would be more abundant, or, in other words, the parasite is the factor, or one of the factors, which controls the abundance of the host. It was suggested by an American entomologist, Asa Fitch, more than seventy years ago, that use might be made of parasites to assist in the control of insect pests. Nothing, however, seems to have been done at that time, and in 1872 a M. Decaux made the suggestion that the Apple-blossom-Weevil (*Anthonomus pomorum*), which was very troublesome in certain parts of Picardy, might be controlled by conserving its parasite. Not until 1880 was the experiment actually made in an area of about 800 trees which were very badly infested and were somewhat isolated from other orchards.

The mother beetle bites a small hole in the developing blossom and inserts an egg, and the beetle larva feeds upon the pistil and stamens. As a consequence, the petals do not open but the bud remains globular and turns a rusty red. The larva changes to a pupa within the so-called " capped " blossom, and the beetle later hatches out and escapes. The usual method of dealing with this trouble had been to gather the capped blossoms and destroy them. Now the weevil is attacked by a small parasite, and M. Decaux pointed out that the destruction of the capped blossoms meant not only the destruction of the weevils, but also that of the parasites, and he suggested that if the blossoms

were collected and placed in such conditions that the parasites could escape while the beetles could not, it would be a wise course to pursue. Consequently the blossoms were stored in boxes covered with fine wire gauze screens, the mesh being such that the parasites could pass through but the weevils could not, and these boxes were placed in the orchards. As a consequence, it was calculated that a million beetles were destroyed in the first year of the experiment, while about two hundred and fifty thousand parasites were released. The experiment was repeated in the following year, with the result that the parasites so reduced the number of weevils that for ten years afterwards the damage done by the pest was inconsiderable. Since that time, in various parts of the world, efforts have been made to destroy the pest by increasing the numbers of the parasite, and in Czecho-Slovakia, for instance, the cocoons of the Nun Moth, which are easily found, are collected and stored so as to permit of the escape of any parasites they may contain without allowing any of the moths to get away.

By such means it is possible to exploit the native parasite and increase its numbers, but, unfortunately, most of the serious pests in the world are insects which have been introduced, usually of course by accident, into the countries where they are interfering with man's activities. Once the possibilities of the parasite were recognised it was suggested that if it could be shown to be the chief controlling factor in the original home of an insect which had become a pest elsewhere, it might be introduced to diminish the

numbers of its host in the country where the latter had become abundant through lack of control.

Now we may refer once more to what was said in the previous chapter about the balance of Nature. The introduction of a new insect into any district tends to upset the balance, and this new insect may or may not be such as to readily fit into the scheme of things. If it does not, it means that there is nothing in the district it has invaded which can keep down its numbers and, as a consequence, it increases and multiplies, seriously interfering with other forms by occupying space and eating up their food. Where it becomes sufficiently abundant and develops a taste for our cultivated vegetation, we recognise the appearance of a new pest. In its native country this pest may well have been a harmless member of the complex of animals and plants and, if so, it was controlled by some agency. It might be that the control was some physical factor, but on the other hand, if the control was a parasite, why not introduce the parasite to control the pest?

The idea seemed plausible to those who first thought of it, and it is perhaps a little unfortunate that one of the earliest experiments in this direction was a most extraordinary success. In California the orange groves were suffering severely from the attacks of an insect known as the " Fluted " or " Cottony-cushion " Scale (*Icerya purchasi*), which sucked the sap and by its sticky excretions gave a hold on the leaves to the spores of a fungus, which assisted in destroying the plants. Investigation showed that the Icerya was a

native of Australia, and entomologists were sent there to observe what it was that prevented this scale-insect from being a pest in its native country. It was discovered that a small ladybird beetle (*Novius* [*Vedalia*] *cardinalis*) fed upon the scale and kept down its numbers. Now a large number of the *Coccinellidæ* or Ladybird beetles feed, both in their adult and larval stages, upon scale-insects and upon aphides or greenfly. The beetles lay their eggs in small batches in the neighbourhood of the food material and the young larvæ crawl about and graze upon the abundant prey. They are, therefore, special predators and not parasites in the true sense of the word. After one or two failures, a small batch of the Novius reached California, where it was carefully looked after in insectaries, and in a short time a large batch of descendants was available for distribution to the orange groves. From the first the experiment was a success, the beetles and their larvæ destroying the scale until the latter almost disappeared from the district. But it is always necessary to keep up the supply of the beetles by breeding in insectaries, as the insect apparently has not succeeded in establishing itself, and the scale either is never completely exterminated in any district or else it reinvades the district after the disappearance of the beetle. The beetle has to be supplied again when the pest once more becomes abundant. Not only has this beetle been successful in California, but in practically every other country where it has been introduced to deal with the Fluted Scale, and one advantage about it is that it is mono-

phagous—that is, the Fluted Scale is its only food. The success of this experiment led to a number of others of the same kind, the results of which were for the most part disappointing, the reason being that it is impossible to foretell whether an introduced parasite or predator will behave in the same way in the new country as it did in its native home. It is brought into an environment which, but for its host, is completely different from the native environment, and, if it survives at all, it may well change its habits and it may even itself become a pest by reducing the numbers of some useful insect. The failures, as a rule, have been due either to the disappearance of the parasite or to its failing to do the work for which it was introduced.

But although we may describe the introduction of parasites or predators as of problematical value for the control of insect pests, by a very careful study of the life-history and habits of the pest and of its relationships with other species in its new environment it is possible, so long as the complex of species in the affected area is not too great, to introduce a parasite with a reasonable certainty of success. Nowhere has this type of work been done better than in the Sandwich Islands, where, by the most careful study of the fauna and flora, which is naturally limited because of the comparatively small size of the area, the entomologists have been able to introduce parasites to control many different pests and always with either complete, or a very marked measure of, success. From the model work done in Hawaii other islands have had similar

successes, and it may be possible some day to get the same measure of success on the large continents, where of course the interrelationships of living things are much more complex and are in perpetual danger of interference from invasion by species from surrounding areas.

It should be clear from what has been said in this chapter that the exploitation of the parasite and special predator requires first of all a study of the habits of both the pest and the parasite, and a knowledge of structure is involved in the study of the relationship of the one with the other. The fact that the study of the environmental complex of the pest has been shown to give good results, further proves the absolute necessity for a thorough knowledge of the whole subject of entomology on the part of anyone who would desire to be an economic entomologist.

CHAPTER IV

INSECTS AND PLANTS

The first and most obvious relationship between insects and plants is that in which the former feed upon the latter. We may take it that the vegetarian type arose very early in the history of insects, whatever may have been the primitive type, so that plants have long been exploited, and insects have become adapted to eat every part. While some attack the roots, others

feed upon or within the stem or trunk, while others again devour the foliage, and still others destroy the flowers. We may also take it that, in the majority of cases, the protoplasm and sap of the plant are what are sought after, but it is interesting to notice that in most cases the wood-borers occur chiefly in trees which are either deteriorating through age or disease, or in fallen and cut timber where the flow of sap has ceased. In the case of the Bark-beetles (*Scolytidæ*), for instance, we describe them mostly as secondary pests, since they do not usually attack trees with a full circulation of sap, and yet some of the secondary pests may become primary and attack healthy trees under certain conditions. It has been shown that very many of these wood-eating insects are quite unable to digest the wood for themselves, but that they contain within them micro-organisms, which convert the lignin into a material digestible by the insect. An interesting example of " Symbiosis " or mutual advantage to both organisms (4).

In connection with the statement just made that the wood-borers attack trees past their best, it is interesting to notice that observations on insect pests in most parts of the world have shown that usually the plants which suffer most are the weakly ones, and we shall return to this subject later on in this chapter.

It seems probable that the earliest vegetarian insects fed upon vegetation in general, and were therefore polyphagous. Specialisation or fine adaptation usually means limitation, and therefore we assume that the monophagous insect—that is the insect which only

has one food plant—has evolved from the polyphagous and has gradually become adapted in its method of feeding, and of dealing with the food internally, to the peculiarities of that particular food plant. But monophagy, so far as vegetarian insects are concerned, has not yet developed to any great extent, and, although no insect is capable of eating every kind of vegetation, the majority have a list of at least several possibilities. In some cases we find a particular species indifferently dispersed over several species of plants, while in others we find that an insect definitely prefers one type of food and only takes to another in the absence of the first as mentioned in Chapter II. (pp. 25, 26).

The Gipsy Moth (*Lymantria dispar*) was accidentally introduced into the New England States of North America in 1868 or 1869. It took from twelve to twenty years to establish itself sufficiently to become a serious pest, and by that time the caterpillars were in millions, stripping the leafage of the woods, fields, and gardens so that in midsummer, over large areas of ground, the vegetation was almost devoid of leaves. Very few trees were immune, so that the range of food of the caterpillars was a very large one. At that time the species showed great vigour, and each female moth laid on an average 500 or 600 eggs. As time went on the fecundity decreased, and, with this loss of vigour, there developed a selective taste on the part of the caterpillars, so that now many trees are immune from attack which formerly were readily eaten. By 1913 it was described as "no longer prominent as

a field or garden pest "(10). And in this short history of the gipsy moth in America we seem to have an epitome of the evolution of the feeding habits of insects. So long as an insect is more or less omnivorous the food is perpetually liable to be changed from generation to generation, but, as soon as a selective taste develops, the spreading out of a species into new areas may cause different strains to develop. Various experiments which have been made indicate that physiological changes do occur so that individuals of the same species divide up into groups; one group confining itself to one type of food plant, while another group concentrates upon another type.

In the case of the belladonna leaf miner fly, already referred to in Chapter II. (p. 26), its normal food plant is henbane, but, in the absence of henbane, belladonna is readily eaten. But Cameron found that it would also eat beet and mangold, and that adult flies reared from larvæ which had been fed upon belladonna would not lay eggs upon mangold and that females reared from larvæ fed upon mangold would not oviposit upon belladonna. He suggested, therefore, that, " within the limits of a single polyphagous species, certain well-defined " biologic " species may be established, each of which shows a marked tendency towards one of their food plants. At the same time, Davidson, working with an aphis (*A. rumicis*) —well known to people who grow broad-beans, as it appears upon them in its black swarms about June— found that it had two life-cycles, one of which passes from the winter host, dock (*Rumex*), to the summer

host, broad-beans, and thence back to dock, while the other spends the winter upon spindle-tree (*Euonymus*), and passes to poppy and also to mangolds and beets, etc., in the summer. He suggested that "if these two parallel life-histories were stable, the question of the influence of the host plants on aphids is an important factor. The two life-cycles seemed to show that the preceding host plant upon which a generation of aphids is produced, has a determining influence on the species of plant subsequently selected by the winged migrants" (8).

In the previous chapter reference was made to the habits of the Woolly Aphis (*Eriosoma lanigera*), and to the fact that rarely the sexual forms appeared upon the apple. Now it is clear that in such a case the life-cycle contains a number of generations of parthenogenetic females on the apple and a few generations, including the sexual ones, upon the elm, and that the apple generations can get on either by continuing during the winter upon the roots as parthenogenetic forms or, rarely, by producing the sexual forms, so that the elm generations are not essential now to the apple generations.

There are other aphides, such as the Spruce-Larch species (*Chermes abietis-laricis*), in which somewhat similar phenomena are observed. This species produces itself parthenogenetically on the spruce and leaves the spruce for the larch to complete its life-cycle and produce the sexual forms, which return to the spruce. Here again the larch is not essential to the continuation of the species which can short-circuit

on the spruce, producing other parthenogenetic generations.

Now in these cases the question arises: Is this the last stage in the reduction of polyphagy to monophagy or is it a distinct phenomenon? It certainly may be argued that the former is the correct explanation, but the point to notice is, that the host upon which the sexual generations are produced is the principal host—in these two cases the elm and the larch, while the apple and the spruce are secondary. If we believe that these species of aphis are on the point of becoming monophagic, we may regard the rare occurrence of the sexual generations on the apple as a remnant of what was once the regular happening and the absence of the occurrence of sexual generations on the spruce as indicating that the spruce-larch species is nearer to monophagy than the woolly aphis. But here in both cases we have an indication of physiological species within the species.

The short circuit, aided by complete parthenogenesis on both the apple and the spruce, is making the apple race and the spruce race independent of the elm race and the larch race, so that in time both these races may become separate true species. It may well be therefore that in many cases monophagy is not so much the result of a species becoming more restricted in the variety of its diet, as of physiological races arising on the different food plants and breaking up what was originally one polyphagic species into several monophagic ones.

So far, therefore, we have seen that the dependence

of insects upon plants for food may indirectly have given rise to new species. But plants may provide food for insects without suffering thereby, and in such cases we find that the plants expect something in return. The production of seeds on a plant necessitates the transference of pollen grains containing the male element from the stamens of a flower to the ovary containing the female element. The ovary usually bears a structure, the stigma, which is sticky, so that the pollen grains readily adhere to it and the grains then grow out a tube which, carrying within it the male element, passes down to the ovary and unites with the ovule.

In the more primitive flowers the wind distributes the pollen, and since the chances of the pollen grains reaching the stamens are very small, the wind-pollinated flowers produce very large quantities of pollen. At the right season of the year the clouds of yellow pollen can be seen being blown from the pine-trees on a sunny day in the British Islands. But early in the history of flower production insects seem to have become useful, and plants began to specialise in two directions to utilise these visitors, for which they began to provide nectar in special glands within the flower and extra pollen as food. In some cases the flowers became massed together so that the inflorescence became conspicuous, although the individual flowers remained small, and this line of evolution was economical in that the mass of flowers formed the attraction and the insect, having arrived, pollinated many flowers within a small area. The elder, hemlock, and daisy are three examples of different groups of plants in which

this massing of flowers has taken place. It has frequently led to a modification of the individual flowers, such that those in the centre of the mass are of different form from those outside: as, for instance, in the daisy, where the central flowers are regular tubes, while the outermost or ray-florets bear the large expansion to the outer side which makes these flowers irregular in form. However it may have been brought about, there is no doubt that the massing of the flowers was an advantage to the plant in connection with insect visits and that the form of the flowers was changed as the result of this massing. In other cases each flower became specialised, so as to ensure that the visiting insect gathered some of the pollen, or, on arrival, deposited pollen gathered elsewhere.

It might be asked, if the flower has both male and female organs, why does it not develop some device of self-pollination, so as to save all this trouble in connection with cross-pollination? The explanation is that there seems to be a law of Nature which holds for most animals and plants that in-breeding is bad for the species and, just as the plants adopt various devices to avoid it, so human beings draw up tables of consanguinity and forbid a man to marry his grandmother. Some plants produce the sexes in different flowers and even on different plants, while most plants ripen one sex before the other, so that, for instance, the stigma is not ready to receive pollen until the stamens of the particular flower have shed what they have produced.

But some flowers might be described as cautious.

The violet, for instance, produces two kinds of flowers: one of which gives nectar and is scented and attractive to insects, while the other never opens, has no nectar nor scent, and sets its seeds without outside assistance. The narcissus and crocus have their stamens so placed that they cover the stigma, and if, as may well happen in the cold weather when these flowers open, no insects arrive, the flower is self-fertile. Various other flowers have moving stamens or stigmas, which change their position as the flower matures, so that the stigmas come into contact with the last ripening stamens and get pollinated in case no insect has brought pollen from elsewhere—*e.g.*, the Lesser Spearweed (*Ranunculus flammula*), *Geranium pyrenaicum*, *Malva rotundifolia*, and others.

But the flowers which have gone in whole-heartedly for insect-pollination have lost this caution and have sacrificed everything to attracting certain types of insect, providing landing stages for them in the form of a large lip, lines of colour so arranged that they are supposed to point to the nectaries, and so show the insect where to find them—hence they have been misnamed "honey-guides"—and elaborate devices by means of which the insect, in seeking the nectar, gets brushed with the pollen from the stamens and rubs itself over the sticky stigma.

If one thinks out this last statement it will appear to be absurd. If the insect gets pollen upon it at the same time as it rubs the stigma, either the pollen gets upon the insect at some part where the stigma does not touch it or self-pollination is indicated. But the flower

overcomes these difficulties usually by ripening the stamens first, so that when the insect becomes dusted with pollen the stigma is not ready to receive it. The flowers have developed various remarkable mechanical contrivances to escape self-fertilisation and to secure cross-fertilisation. Space will not permit us to enter into details, but the reader who is interested may refer to Hermann Muller's (16) excellent book on the subject, or to the small volume by Sir John Lubbock (15) on *British Flowers and Insects*.

The specialisation of flowers in relation to insects has gone so far that many are dependent upon special insects for their pollination, and, without the insects, the plants can produce no seed. The Yucca plant, for instance, is entirely dependent upon moths of the genus Pronuba. The flower is not fitted for self-pollination, and, just as the flower has become dependent upon the moth, the latter has become dependent upon the flower. She lays an egg in the stigma of the flower and as the caterpillar has to feed upon the contents of the developing fruit-pod it is essential that the pod should develop. To ensure this the moth visits the stamens and deliberately collects a mass of pollen, which she then carefully applies to the stigma.

The fig-trees produce a most peculiar inflorescence. The green fig, if cut in two, will reveal a cavity which communicates with the exterior by means of a small pore at the apex of the fig. Examination will reveal the fact that the walls of the cavity are lined with numerous minute flowers, the succulent fruit being the swollen end of the flower-stalk, just as the pulp

of the apple is the swollen stalk which has bulged up all round the ovary. These fig inflorescences are the haunt of large numbers of minute wasps (*Blastophaga*), the females of which lay their eggs in certain flowers, and, by walking over the others, transfer the pollen from stamens to stigmas. Without these insects the wild figs cannot produce seeds, and without the figs the insects cannot reproduce. The Monkshood (*Aconitum*) is dependent for its pollination upon the humble bee, and a map of the distribution of plant and insect shows that the range of the aconitum is within that of the bee. When red clover seed was first sent to New Zealand a magnificent crop resulted with abundance of flowers but, to the surprise of everyone, no seed was set. This was due to the fact that humble bees did not occur there, and they had to be introduced from this country.

From what has been said it is quite clear that plants provide nectar and pollen in return for the work done by insects in setting their seed; but there are other plants which provide food and shelter for ants, apparently in return for the protection against other ants and grazing animals provided by these pugnacious little insects. The Cecropia or Trumpet-tree of South America, which grows to about 20 feet in height, has the internodes of the stem hollow, which is not a very remarkable thing, but the nodes provide only a thin layer of tissue between these internodes. The leaves mostly grow at the top, and just above the base of each leaf-stalk there is a slight depression in the stem where the wall is very thin

and soft. The internodes are usually occupied by hosts of a small ant. The queen ant first makes her way into the tree when it is young, perhaps 6 feet high, by biting her way through the weak spot in the wall of the internode. She then settles down in the excellent chamber provided for her and the door through which she has entered rapidly grows tissue and becomes closed. She rears her first batch of less than a dozen workers in the cavity, and, when they become adult, they once more open the door to the exterior. Now the tree not only provides this excellent accommodation, which the ants extend by biting through the thin nodal partitions, but on the hairy base of the petiole of each leaf there develop numbers of small yellow bodies which, so far as is known, are of no use whatever to the tree. These are the food upon which the ants live, and they gather them and store them in the nest in the stem. It appears, then, that the Cecropia provides both food and lodging for this particular ant, which is very pugnacious, and, if the tree is in any way disturbed, hordes of individuals swarm out and are ready to attack an intruder. Many trees in South America suffer from the ravages of the "leaf-cutter" or "parasol" ant, which removes the leaves to underground nests, where they are used as soil for the growth of fungi. The Cecropia is apparently immune from these attacks, so it is perhaps justifiable to assume that this immunity is due to the presence of the little Azteca ants.

In the same way an Acacia in Nicaragua was discovered by Belt (2) to provide homes for ants in large

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thorns at the base of the leaves, and also scattered nectaries, producing sweet sap, and small food bodies at the apices of the leaflets, and he suggested that these ants kept the tree clear of the leaf-cutters, and also prevented animals from grazing upon the leaves. And just as plants have become adapted to insects, so the latter have become adapted to plants, the form of mouth-parts being suited to the form of the flowers frequented. Those insects which sip their nectar at the open flowers have short and broad paint-brush-like mouth-parts, while those which visit the long tubular flowers have one or more of the mouth-parts lengthened out so that the nectaries may be reached. Pollen eaters have hairy mouth-parts suitable for sweeping up the pollen grains, and those insects, such as the bees, which gather and store up pollen, have elaborate fur coats in which the pollen grains become caught, and, in addition, some of the higher bees have pollen baskets and special brushes upon the hind legs.

And now to return to the subject of plants as the food of insects. When speaking of parasites in the last chapter, we saw that the ideal parasite did not commit suicide by wiping out its host, and, in the same way, there is a balance between plant-eating insects and the vegetation, so that the former do not become so numerous as to destroy their food materials, We saw, however, that some parasites were apparently destroying their hosts—*e.g.*, the cuckoo-bees—and in the same way there are some plant-killing insects.

The Cochineal insect, mentioned in the first chapter, was introduced into India from Rio de Janeiro in 1795 with a view to starting the dye industry in that country, but either the wrong strain of bug was introduced or, under the different climatic conditions, it was useless commercially. However, it became wild and fed upon the prickly pear (*Opuntia monocantha*), and in twenty years it had practically cleared Southern India of this troublesome weed. In 1913 this Indian Cochineal was introduced into South Africa for the express purpose of destroying this same Opuntia, apparently with satisfactory results. The small Lantana Fly (*Agromyza lantanæ*) lays its eggs in the immature berries of the lantana, which is its chief food plant. The maggot feeds upon and destroys the seed. Wherever the lantana has reached a country with a suitable climate it has spread very rapidly over waste ground, and is apt to spread where it is not wanted. In Hawaii and certain other places this fly has been exceedingly useful in destroying the weed. It will be noticed that, in the case of the Cochineal insect, it was after introduction to a new country that it became a plant destroyer, and, in the same way, the lantana plant is a native of South America, and the successful experiments in its control by the fly have been in Hawaii, Fiji, and Australia.

An experiment is now in progress in New Zealand, where the bramble is a very free-growing weed. Dr. Tillyard (19) has been introducing numerous bramble-eating insects with a view to destroying the plant. This is a very risky experiment because, under

changed climatic conditions, these bramble-eaters may well turn their attention to some other kind of food, but the principle is justified on what has already been said.

It has already been mentioned that the protoplasm and sap of the plant are the main food of vegetarian insects, and therefore, with a view to preventing insects destroying our food plants, researches have been made upon the sap with a view, amongst other things, to discovering the qualities which attract insects.

The quality of the sap varies from time to time in the individual plant, and observations have shown that where, for instance, Cacao or Citrus are protected from wind or by shade trees, sucking insects, such as Scale, Aphis, or Thrips, are less troublesome than when the plants are exposed to wind and sun. In other words, loss of water, through transpiration of the plant, which increases the osmotic pressure of the sap, favours the insect. Therefore irrigation of cotton has been suggested as a means of reducing the attacks of the cotton thrips in the Sudan. Chemical examination of the sap shows that the quantity of sugars varies, and experiment has also shown that increase in the quantity of reducing sugars is associated with increased damage by insects. In the normal process the sugars in the plant are replaced by organic acids, and increase in organic acids increases the resistance of the plant to insect attacks.

Experiments have therefore been made with a view to controlling the nature of the sap so as to make the plant resistant to insect attack, and the simplest type

of such experiment is treating the ground with some chemical manure. It has been shown in the case of sugar-cane, cotton, and various other crops, that the nature of the soil affects the resistance of the plants to insect attack, and, speaking broadly, we can say that this is largely due to the fact that each type of plant requires certain soil conditions in order that it may attain its maximum vigour and that other conditions affect its health and make it less resistant. Sugar-cane in Trinidad has suffered for many years from the attacks of a small bug, the sugar-cane Froghopper (*Tomaspis saccharina*), and in 1914 an entomologist was sent out to investigate the problem. He showed that wherever cane was grown in badly drained soil or under conditions which reduced its vigour the froghopper did the greatest damage (21). More recently it has been found that the acidity of the soil is an important factor, and that on the limestone areas and on limed soil froghopper does much less damage. This may be explained on the ground that the lime affords the ideal conditions for the vigour of the plant or, possibly, and perhaps more probably, the lime acts directly by neutralising the acidity.

In India, the tea-plant is, in many places, seriously damaged by a small bug known as the "Tea Mosquito" (*Helopeltis*), which appears in vast numbers and sucks the sap so that the plants wilt and the leaf is useless. Andrews, the entomologist to the Indian Tea Association, having tried all the usual methods of control of the pest itself, decided to start at the other end and to attempt to make the plant immune

from attack. By careful examination of the soils and the chemical composition of the leaf of the tea-plant he came to the conclusion that, if it were possible to increase the proportion of potash in the plant, the sap would be less attractive to the bug. At first he tried injecting fluids into the plant, a method which had been tried with indifferent success on trees by many experimenters. At this time Dr. Gough, of the Egyptian Entomological Service, made a suggestion which led Andrews to experiment with the roots. He unearthed a small bunch of roots and placed these in a solution of a soluble potash salt. This salt was readily taken up by the roots into the plant, and in about three weeks the plants so treated, which had been badly attacked by the pest, had taken on a new lease of life and were producing fresh leaves undamaged by the Helopeltis. It was noticed that the bugs attempted to suck the sap, but that they seemed unwilling to continue, and that the punctures made by the mouth-parts healed up without apparently in any way damaging the leaf (1).

Here then is a new principle of insect control—making the plant immune from attack—and this method has a great future before it. Here again we see that the individual who is going to undertake the control of insect pests has another large field of knowledge to explore. He must have a good grounding in botany, especially in the physiology of plants, and in the relation of the plant to the soil, in order that he may, like a great general, be prepared at all points to meet the attack of the enemy.

CHAPTER V

THE GEOGRAPHICAL DISTRIBUTION OF INSECTS

We do not seem to have any good words in the English language for distinguishing between the actual process of dispersal of animals and plants and the result of this process which can be mapped out for each species. I should have liked to head this chapter with the title "Insect Dispersal and Distribution," but, according to the dictionary, it would have been mere redundancy, equivalent to the "erred and strayed" in the Prayer Book.

We may take it that every organism requires a certain amount of space for itself, and that, obeying the law to reproduce its kind, each individual is having to struggle for the requisite space with other individuals, so that there arises the necessity for dispersal. And this necessity for space is backed by the necessity for food, so that we may describe as normal dispersal a spreading-out of a species owing to the necessity for food and space.

And the amount of space required by an individual seems to be unduly large in many cases. For instance, there is a minute water-beetle (*Bidessus minutissimus*), which occurs in certain southern and western districts of Britain and in south-western Europe. Its length is only about 1·5 mm. (about 3/10ths of an inch). I have, on several occasions, kept specimens alive in tumblers

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of water, but in every case where more than one specimen has been placed in a tumbler there have been deaths within a short time, and, within a few months, either all have died or only one has survived. But I have kept single specimens alive for three years at a time. We may take it, therefore, that the tendency to crowding due to reproduction—crowding being a very different thing for different species, and perhaps for one species under different conditions—leads to normal dispersal in all directions, so far as this is not prevented by natural barriers such as oceans, climatic conditions, types of country such as mountain ranges, etc., types of vegetation such as forest, etc., each different species being limited by different barriers according to its natural habits. But undue crowding has strange results. Everyone has heard of plagues of locusts, and these are swarms of individuals all migrating together. Egg-masses are buried in the ground by the ovipositing females, and great numbers of individuals lay their eggs within a limited area. The young "hoppers" hatch out and, for the first few days, content themselves with feeding upon the vegetation where they emerge. But as the food-supply becomes exhausted, the migratory instinct suddenly arises and the whole swarm moves off, hopping sedately and feeding and growing, and, when the adult winged stage is reached, continuing the migration by flight. It is now known that there are two phases in the life-history of the locust; one migratory and the other non-migratory and the two are sometimes so different in appearance that they have been described as different

species. In the case of one species, and it is probably true of others, it has been shown that either phase can be induced, crowding producing the migratory form and plenty of room producing the non-migratory (14).

At odd times, swarms of dragon-flies occur in various parts of the world, and there is a widespread belief that droughts and dragon-fly swarms are in some way associated. The gradual reduction of the water in a pond, owing to want of rain, necessitates the crowding of the inhabitants, and this would probably enable the dragon-fly nymphs to capture food more easily than under normal conditions. This might cause individuals, otherwise not destined to emerge as winged individuals until the following year, to shorten their life-cycle so that two batches would appear together in one season. The food-supply of the adults, which consists of winged insects, would thus run short, and this might lead to migration.

There appear from time to time in the newspapers reports of caterpillars stopping trains, and perhaps some people picture mountains of them through which the locomotive cannot push its way. As a fact, though the numbers are very great, it is the greasy fat of the squashed individuals which makes the rails slippery, and the train is held up because the engine wheels cannot get a grip; but the origin of these swarms of "army-worm," as they are called, is interesting. Examination of a swarm shows that it consists of about 95 per cent. of one species, and that the other 5 per cent. are made up of perhaps nine or ten other species and the explanation seems to be that,

owing to some upset in the balance of Nature, large numbers of the mother moths of the dominant species have survived to lay eggs or large numbers of the caterpillars have escaped parasitisation. Owing to the excessive numbers of caterpillars, the food-supply is quickly exhausted, so that not only the caterpillars of the pest species are affected, but all other caterpillars which normally feed upon the same plants. Starvation causes them all to migrate together as one swarm. It may be that many other migrations of insects are caused by starvation. Each year various species of butterflies reach these islands from long distances. The Painted Lady (*Vanessa cardui*) arrives in May or June from North Africa, and Skertchly has recorded the fact that near Sowakin, in Nubia, in March, 1869, he observed the pupæ of this species so numerous that almost every blade of grass seemed to bear one (18 and 22). And this suggests that in this case also starvation may be the cause, or one of the causes, of the migration. These butterflies, after arriving here, lay their eggs upon thistles, and a fresh generation of adults hatches out about August. But the species never survives the winter here, so that we are each year dependent for this, and a number of other insects, upon the arrival of individuals from some other country.

In the cases cited the migration apparently leads to nothing, no obvious extension of range of the species being attained, and yet such migrations may well be successful from time to time when a species reaches some area which is suitable as to climate and other

conditions, so that it can hold its own in the struggle for existence with the native species. The examples given also show that the insect may make its migration either in the young or in the adult condition, or in both. And normal dispersal also may take place before the insect has attained maturity. Gnats and Mosquitoes lay their free floating eggs, the former in small batches or "rafts," the latter singly, and, although many species lay in stagnant water, others do not and such eggs may from time to time be carried far from where they were laid. Their larvæ may be carried by floods, and the adults are known to make migrations between breeding and feeding areas (17).

In certain bugs—*e.g.*, *Diplonychus* and *Belostoma*—the eggs are attached to the upper wings of the male, so that dispersal of these insects commences at once if the male wanders from the mating centre. Some insects disperse in the nymphal or larval condition. For instance, as already mentioned, in the case of some parasites, the young larva has to find its way to its food-supply. The Melöe, one of the so-called "oil-beetles," deposits her small yellow eggs to the number of about ten thousand in three or four batches in holes which she digs in the surface of the ground. In a few weeks the young larvæ hatch out and, after a short interval, they become very active, climbing up the vegetation and getting into the flowers. Here they await the arrival of flying insects and they immediately attach themselves to hairy ones. Their future depends upon their getting upon certain bees and, unless they succeed in this, they perish, and it is

because the chances of success are so poor that the mother beetle lays so many eggs. It is true, in most cases, that large numbers of eggs or offspring indicate a precarious existence before maturity is reached. Thus, the Melöid beetles are dispersed in their first larval stage, being carried to the nests of bees where they ultimately devour the bee's larvæ and the honey paste stored up for it.

The caterpillars of certain moths, for instance the Gipsy Moth, already mentioned, during the first week or two of their lives are the main means of dispersal of the species. The moths are rather heavy and do not fly far. The mother moth lays her batches of eggs low down on the trunk of the tree, covering them with yellow hairs shed from the apex of her body. The caterpillars, when they hatch, possess a number of very long hairs, many of which bulge out into an air-filled vescicle. These little creatures climb to the tops of the trees and allow themselves to be wafted away by the breeze, and experiments, made by setting up wire-netting screens painted with bird-lime or other sticky material, show that these larvæ are often carried great distances from their hatching place. Many insects disperse normally in the adult condition: for instance, fleas, whose life-history has already been referred to (p. 39), attach themselves to their hosts when they attain the adult condition and are carried about by them, dropping off wherever they may be when the time comes for oviposition.

These methods of dispersal so far described are all more or less deliberate, but accidental dispersal plays

an important part in carrying insects across barriers which otherwise might for ever restrict their range. For instance, winds, especially whirlwinds and hurricanes, and floods may transport insects very considerable distances, especially considering that many of them are very tenacious of life. In mid-Atlantic, on a journey to South America some years ago, various odd insects arrived on the ship from time to time, probably having been caught up by a sudden wind and carried upwards and out to sea. On a recent visit to the West Indies, when between four and five hundred miles out of Avonmouth, numbers of small pyralid moths appeared resting upon the calm surface of the sea and rising up on the approach of the ship. Some of these flew in at portholes, so that I was able to capture them and have them identified. The species* has a world-wide distribution, but it can scarcely be suggested that the numerous individuals had been trying to create a record of crossing the Atlantic. It seems more probable that they were caught up by the wind and carried out to sea. Many insects can safely cross the sea under the bark or in the wood of trees which have been torn from their hold by floods and carried down rivers, as experiment has shown that many withstand complete submergence for long periods, so that such voyagers have an excellent chance of reaching new territory. Man is perpetually transporting insects from place to place. Ships have carried cockroaches, flies, and other insects from one country to another, and market produce has been proved many times to be the source of supply of insect pests.

* *Nomophila noctuella*, Schiff.

The Americans indignantly repudiate having sent the Mediterranean Flour Moth (*Ephestia kühniella*) to Europe, but if they did, as seems probable, Europe has supplied them with more pests than it has received from them. The Brown Tail Moth (*Nygmia phæorrhœa*) was introduced into the United States about 1890, probably in nursery stock from France, and has been exceedingly troublesome as a pest of fruit-trees. The Colorado beetle (*Leptinotarsa decem-lineata*) has several times reached Europe from the States, and the list of accidentally introduced pests for every country is very extensive.

In order to stop this introduction of pests, each country has now developed a system of inspection of imports, and requires either certificates from reliable authorities that the materials have been disinfected and are pest-free, or more usually that disinfection, usually by fumigation, should take place before the goods are removed from quarantine. Each country has an insect black list, but in this country we have a comparatively small one, because, fortunately, our climate is unsuitable for most of the serious pests: but in warmer countries, such as the United States, the Inspectors of the Department of Entomology are perpetually on the watch to keep out the few remaining first-class pests which have not yet reached them. But the laws with regard to importation of goods liable to bring insect pests into a country are all based upon knowledge of the habits of the insects as acquired by a very careful study of them, and in connection with this importation of pests there is still

very important work to be done. It is easy to fumigate cotton seed, grain, and various other seeds, but many imported foodstuffs cannot be so treated.

At the present time the Entomological Department of the Imperial College of Science in London, under the ægis of the Empire Marketing Board and the Forest Products Board, is carrying out experiments in connection with stored products and timber with a view to reducing the immense losses caused by insects, and for this work men thoroughly versed in the structure and habits of insects are essential.

In conjunction with this work it is important that research should be carried on in the colonies with a view to reducing and eliminating the infection of such goods before they are shipped. The colonies themselves have long realised the value of trained entomologists in controlling the pests of the various crops, and time has shown that the training of these men must be broadly based so that they may be able to work, as Andrews did, not only by destroying the insect pest, but by making the plant immune from attack.

Consequently, whereas not so long ago it was difficult to find posts for enthusiastic entomologists, now it has become difficult to find men for the posts. The present economic entomologists are the pioneers in a work which is going to attract much more attention than it has done hitherto. We have reduced the dangers of malaria, which not so long ago was responsible for half the deaths in the world every year, by controlling the mosquito, and we shall

ultimately overcome the insect menace to our food-supplies and our commerce which, without the aid of the entomologist, would most certainly overwhelm us.

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INSECTS & INDUSTRY

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PREFACE

THIS little book has been prepared for the publishers at the suggestion of Professor Balfour-Browne. Though the subject is treated as a separate volume, it may well be read as a supplement to his *Insects* (No. 45 of this Library), and, it is hoped, will serve to interest readers in a branch of applied biology, which, as the years pass and industry advances, more and more nearly affects their own affairs and well-being.

INSECTS AND INDUSTRY

CHAPTER I

INTRODUCTORY

THE study of the relationship of insects to industry, including agriculture, the oldest of all industries, forms that branch of biological science which is termed economic entomology. Its aims and objects are primarily to assess the nature and cause of the losses inflicted on industry by the activities of insects, to ascertain how far these losses can be prevented or avoided, and to devise practical measures of remedy and prevention.

Economic or industrial entomology requires for its successful practice not merely a knowledge of insects or a knowledge of industry, but a knowledge of the relationship of these to one another, and it calls for ability and skill not necessarily possessed by the academic entomologist. It is a branch of what Francis Bacon called "history mechanical," a branch of "such natural philosophy as shall not vanish in the fume of subtile, sublime, or delectable speculation, but such as shall be operative to the endowment and benefit of man's life."* Its methods are precisely those of his "history mechanical," not only "to minister and suggest many ingenious practices in all trades," but "further to give a more true and real illumination concerning causes and axioms than is hitherto attained."

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* *The Advancement of Learning,* Book II.

We have quoted Bacon because there is in some minds a tendency to regard the application of a science to industry as a degradation of that science, and to consider that the methods of applied science are less exact and its standards lower than those prevailing in the academic world. That view of applied science is slowly being dispersed, but it is necessary to remember that it exists because for many years the progress of economic entomology has been retarded by its advocates who were more concerned with "subtile, sublime, and delectable speculation" on their pet theories than they were with the advancement of learning.

Another mistaken conception regarding economic entomology is that it is concerned mainly with the destruction of insects and, in particular, with the destruction of insects by means of poisonous sprays and gases. While it is true that a knowledge of the preparations and application of insecticides is essential to the economic entomologist, it forms only a part of his equipment, and to consider that economic entomology consists mainly in applying insecticides is just as erroneous as it would be to say that the writing of prescriptions constituted the major part of the practice of medicine. As the medical practitioner is concerned with the diagnosis and prevention of disease, so the economic entomologist is concerned with the assessment of the losses caused by insects, with the origins and causes of those losses, and with the devising of ways and means of preventing them. As the scientific study of economic entomology progresses, the present somewhat indiscriminate use of insecticides will be abandoned, and will be no more representative of applied entomology than the time-honoured bottle of medicine is to-day representative of the methods of preventive medicine.

Paradoxical though it may seem, the destruction or annihilation of insects constitutes only a minor part

of the economic entomologist's work. In fact, one of the essential qualities in the economic entomologist is that he should be able to keep insects alive. Unless he has acquired the knowledge and skill necessary for the rearing of insects, knowledge and skill obtainable only with long practice, and even then more often a gift of nature than an acquired skill, he cannot study his subjects nor can he understand them. Adequately to study the habits and life-history of even a single insect is the work of years, and it can be successfully pursued only after many trials and vexations.

Even for the proper study of the destruction of insects by insecticides it is necessary to rear large numbers of them. In some experiments recently carried out in the Entomology Department of the Imperial College of Science, to study the destruction of insects by freezing, no less than two thousand eggs of a small moth (*Plodia interpunctella*) were used in each experiment, and enormous stocks of insects have to be reared in order to secure adequate supplies for experimental work. One of the major items in the cost of equipping the economic entomologist is that entailed in the erection and equipment of special insect houses or insectaries, in which the conditions of temperature and moisture can be regulated to suit the exact requirements of the insects to be studied. This rearing of insects requires a knowledge of many branches of biology, and the up-to-date economic entomologist frequently includes among his staff scientists other than entomologists, whose duty it is to experiment and advise on such matters as the regulation of temperature and moisture conditions in the rearing of insects, the proper preparation and concentration of poisonous gases used in control work, the chemistry of insecticides and the relationship of plant diseases to insect attacks.

It is in the early stages of his work that the

applied entomologist makes most use of his entomological knowledge; in the later stages he may find himself studying agricultural practice, or forest operations, or methods of storage and marketing, for as soon as he is ready to apply his entomological knowledge to industrial problems he must ascertain at which stage in the industry it can best be applied, having due regard to the convenience of the industry, the costs of application, and the prospect of practical results. He can ascertain these necessary facts only by acquiring a first-hand knowledge of the industry and by securing the confidence and goodwill of the industrialist.

In tackling most insect problems the entomologist's methods are much the same, and follow a fairly well-defined line of work. His first step is to ascertain or determine the identity of the insect or insects responsible for the damage or losses caused. Here he meets sometimes with two difficulties. First, it occasionally happens that the insect is an undescribed one, and unless the entomologist is himself very well acquainted with the group to which it belongs he must submit it to an expert and await his report on it. In this country and throughout the Empire the central institutions for the description and naming of insects are the Natural History Department of the British Museum and the Imperial Bureau of Entomology. These two institutions work in the closest co-operation with one another, and form, so to speak, the foundation of our Imperial economic entomological services. The correct description and naming of our insect pests is the basis of economic entomology, because until these pests can be readily identified, and until they have been given a name which all authorities in all countries will accept and use, they cannot be properly referred to in reports or other publications. Fully and correctly to describe an insect is no easy matter. It requires an extraordinarily wide

knowledge of insects in general, and a detailed and highly specialised knowledge of some particular group. The days when outstanding naturalists like Linnæus could profess familiarity with most of the known insects of a continent are long past, and to-day one of the serious causes of delay in the progress of entomology is the lack of systematic entomologists who can overtake the huge task of describing, naming, and classifying the enormous number of insects which our economic entomologists are submitting to museums and institutions throughout the whole world. Of the importance of this work there is no question. Once an insect is identified, all that is known concerning it can be found in the literature of entomology; until it is identified that literature is as a sealed book concerning it.

The correct identification of an insect and the study of the existing information on it contained in the literature are the first steps towards the understanding of all insect problems. One of the most important advances made in the development of entomology in our Empire was the establishment in 1910 of the Imperial Bureau of Entomology, which, in co-operation with the British Museum, insures the proper identification of our insect pests, and by the publication of the now indispensable *Review of Applied Entomology* enables the economic entomologist, even in the remote outposts of the Empire, to keep abreast with the recent literature of his subject and the new knowledge it has to convey.

The second difficulty encountered by the entomologist facing a new problem is to ascertain precisely which of the many insects he finds associated with the losses he is investigating is the primary and direct cause of trouble. This is by no means so simple as it may appear, and A. S. Packard, one of the first American forest entomologists, has related how, when investigating the dying of the coniferous forests of the

eastern United States, he ascribed the dying of the trees to the work of certain bark-boring beetles which occurred in tens of thousands, and completely overlooked the real and primary cause of the damage—namely, the so-called "spruce bud-worm," a Tortricid moth (*Cacæcia fumiferana*), which by the time he visited the district had left it for fresh woods and pastures new.

Such instances in which the attacks of a primarily injurious insect are followed by an increase of insects of secondary importance are especially frequent in forest entomology, but they may occur in all industrial entomological problems, and must always be expected and studied.

Sometimes it happens that one has to tackle other insects than the primarily injurious one. In Kenya one of the insects most injurious to coffee cultivation is a scale insect, the "Mealy Bug," (*Pseudococcus citri*). This insect can be kept in check by the use of insecticides, and by encouraging certain insects which are predacious and parasitic on it; but even when a plantation has been sprayed and rid of the Mealy Bug, an ant (*Pheidole punctulata*) carries the bug into the plantations again and so reinfests them. This ant obtains a sweet secretion from the Mealy Bug and so tends it and farms it out on the coffee bushes. *Pheidole punctulata* also destroys the predaceous and parasitic enemies of the Mealy Bug, and the problem in Kenya is now just as much how to destroy the ant (*Pheidole punctulata*) as it is how to destroy the Mealy Bug (*Pseudococcus citri*).

In ascertaining the cause of damage to a crop or product, the problem is not always to distinguish as between one insect or another as the real source of trouble. Not infrequently, as in agriculture and forestry, the difficulty is to decide whether the failure or destruction of a crop is really the result of insect attack at all, or whether the original source of trouble

may not arise from unfavourable soil conditions, or from the attacks of some fungus or bacterial disease, or even from both these factors together.

In the larch woods of the South of England one frequently finds dying trees occurring here and there in groups, which, on inspection, are found to harbour the grubs of a long-horned beetle (*Tetropium gabrieli*). Formerly it was thought that this beetle was the cause of the larch dying in many districts. We now know that the beetle is only of secondary importance, and that its presence is almost invariably an indication that the soil conditions are bad, and that in consequence root rot in some form has set in.

Tetropium gabrieli is a favourite food of the woodpeckers and these birds peck and hack at the bark of infested trees to get at the *Tetropium* grubs. In doing this they expose the richer red of the inner bark of the larch, and their work can for this reason be seen from a long way off. To the knowing forester it calls attention to the presence of the *Tetropium* beetle, and frequently enables him to recognise that soil conditions are amiss when otherwise he would quite excusably overlook them for quite a long time. Dense larch woods are not easily traversed or inspected, and the *Tetropium* beetles, by attracting the woodpeckers, which in turn attract the attention of the forester, are actually more beneficial to his interests than they are injurious.

Bearing in mind all these complex relationships of insects to one another, and of insects to plants, and plants and soil conditions to insects, the entomologist ascertains just which insect is the most important in relation to his problem and decides to tackle it. His next step is to study its habits and life-history. It may be that in looking through the literature relating to it he finds that its life-history has been described or partially described or "worked out." If the description is full and detailed and gives the particular

information wanted as a basis for the study of control measures, a new study of the life-history may be unnecessary. Even so, the experienced entomologist invariably checks up or "confirms" the work of his predecessor, at least in so far as it relates to the salient features of the life-history or to points of special importance for his particular problem. His object in doing this is to insure that he may devise the best kind of control measures, and apply them at the time or times when the insect is most vulnerable.

If the published accounts of the life-history are too meagre or too general to form a sound basis for the devising and application of control measures, then the insect must be studied anew. In doing this the entomologist may use previous work as a general guide, although in actual practice it is sometimes wiser and safer to ignore previous work all together.

One of the surprising features of economic entomology is our meagre knowledge of even our most important pests. In this country, for instance, we have no complete account of such common pests of agriculture as the "wireworms," the larvæ or grubs of certain Elaterid beetles, although these insects have been known to generations of farmers and exact a heavy toll of all their crops. The same holds true almost for the majority of our native insect pests, and one of the crying needs of economic entomology in this country is for better, fuller, and more fundamental studies of insect life-histories.

The reasons for the neglect of this biological work are various. In the first place most of our entomological work is done in the universities or in research institutions linked up to the universities, and as the university summer terms end just when insect activity is at its height in this country, the investigator must either relinquish his work or his vacation. Too often, perhaps, the work is relinquished. Again, to study an

insect's life-history properly requires several years' work. Failures in rearing experiments are frequent, and these prolong the time necessary for a complete study, while the young investigator, who is frequently aspiring to some higher degree, is better advised in its interest to undertake some anatomical or morphological research, which he can abandon and resume again at will, independently of the seasons and with fairly certain assurance of "results" in one or two years' time. Entomological literature is strewn with half-finished biological studies, and for one really useful paper on the life-history of some important insect there are usually half a dozen relating to its structure and anatomy. For example, Straus Durckheim's exhaustive monograph on the anatomy of the common cockchafer was published in 1828, but an equally thorough account of its life-history is still to be written.

It is neither desirable nor necessary further to discuss that matter here, but it is important to note that for various reasons the teaching and study of the identification and classification of insects (systematic entomology) and of the habits and life-histories of insects (insect ecology) are neglected in our universities, and that these two branches are the basis of all sound entomological investigation and research.

To those who in their younger days reared silkworms and puss moth caterpillars, the rearing of insects may seem a relatively simple matter requiring no great philosophy and no great technical skill. When, however, insects, some of them often extremely small and delicate, have to be reared in large numbers and studied in all their stages from egg to first stage larva, and so on to the adult insect, the task is by no means easy.

In the first place the insects must be kept from flying or crawling away, and, although confined, must be kept under conditions as nearly resembling those

of their natural habitat as possible. Some insects will not mate in too close confinement, or, if they mate, fail to leave offspring. Then they must be fed, and many insects are extraordinarily particular in their selection of food. If the food is a plant it must be kept fresh or frequently renewed, if it is some substance such as cheese or dried fruit it must not be allowed to grow mouldy nor must it "dry out." Some insects require moist atmospheric conditions, others prefer dry. Many insects bore in bark and wood, and if removed from their burrows for purposes of study cannot be induced to re-enter them. In actual practice the successful rearing of insects and the building up of large stocks of them is one of the strictest tests of the entomologist's ability. Time and again stocks diminish and die off for no apparent reason. Parasitic insects, moulds, and predacious mites invade their breeding quarters. The night watchman or the caretaker turns off the heat from the insectary or incubator where some specially precious batch of caterpillars are being carefully nursed, or, if one is engaged in field work, wireworms or cockchafer grubs destroy a batch of carefully reared food plants or unexpected frosts kill both food plants and insects.

These and many other accidents test the entomologist's philosophy, and meanwhile his client the "practical man" is shouting for results.

When the habits and life-history of the insect have been studied, the entomologist usually "confirms his results"—that is to say, he repeats his work—at the same time correlating the results obtained in the laboratory or insectary with observations made "in the field"—that is, in the insects' various natural habitats. The term "field work" is used for such work, whether it is conducted in a field, a forest, or a factory.

At this stage the entomologist should have acquired the following information:

1. The identity and zoological position of the insect concerned, together with a knowledge of its country of origin, distribution, and economic status.
2. The host plant or food of the insect, its methods of pairing and egg-laying, its normal rate of development and increase, and the appearance and distinguishing characters of all its various stages.
3. Its relation to the crop or product on which it feeds, its natural enemies, and its general reactions to weather conditions and industrial practices—*i.e.*, how it spends the winter, when it appears in spring, and so on.

When all this information has been acquired the entomologist is in a position to consider the ways and means of "controlling" the insect—that is, of reducing or preventing its depredations. The economic entomologist rarely exterminates an insect, such extreme measures being successfully achieved only by collectors of rare butterflies.

The first and most obvious step in this direction is by means of better hygiene. The burning of stubble and weeds on the farm, the pruning of dead wood and cleaning of lichen off the trees in the orchard, the removal or burning of brushwood or "slash" in the forest, the sweeping of the flour mill or the chocolate factory, the "cleaning up" of the timber yard; all these measures mitigate against the breeding of insects, and, if frequently and thoroughly carried out, go a long way towards reducing insect infestation in general. Unfortunately such measures are rarely popular with or satisfying to the entomologist's client. Something more drastic and more spectacular and difficult is wanted. It is, too, quite often necessary, and so we come to the next line of attack, an attempt to mitigate the insect nuisance by some

slight modification of industrial practice. Improved tillage and drainage, richer manuring, the rotation of crops, and the practice of early or of late sowing, are modifications of agricultural practice, which assist in controlling the increase of insect pests or in "dodging" their ravages. In forestry the regular thinning of woods resulting in the early removal of dying and dead trees, the rapid removal and "conversion" of felled timber, and the growing of "mixed" woods (comprising several different species of tree instead of pure woods consisting only of one species) are well recognised methods of insect control, and are at the same time sound "silvicultural practice."

In the timber-yard, proper piling of lumber, seasoning of the timber by means of the steam kiln, and regular overhauling or inspection of stocks are valuable preventive measures against most of the insects which attack timber.

In dealing with insects affecting foodstuffs and other plant and animal products stored at our docks and warehouses, such measures as the regular periodic fumigation of barges and lighters, frequent whitewashing or distempering of wharves and stores, improved ventilation, lighting, and heating of such premises, and systematic grading and segregation of produce are within the power of most business firms and are well worth their extra cost. The day is coming when the more enlightened manufacturers, merchants, and brokers will insist on these measures as part of the normal duties of the wharfinger and warehouseman.

Even in the humble sphere of the household cleanliness, good ventilation, and central heating will confer a freedom from insect pests, which is in too many dwellings still unattained. Lice, fleas, cockroaches, bed bugs, and flies owe their unwelcome presence in houses to the lack of cleanliness and lack of attention on the part of the ignorant or indolent householder

to such matters as the airing of clothes and bedding, the scrubbing of sinks and pantries, and the emptying of the dustbin.

If such hygienic measures and improved practice fail to cope with the insect problem, the entomologist has to resort to more strictly technical methods. These are described in later chapters.

CHAPTER II

DAMAGE AND LOSS CAUSED BY INSECTS

WITHIN recent years the part played by insects in reducing the volume or value of our crops and stores has been increasingly impressed on governments and public bodies.

The war impressed upon private soldier and War Office alike the importance of the contemptible louse, which on the Western Front alone was during 1917-18 responsible for more than one-half of the inefficients withdrawn from the front line to the rest camps or bases, and acting as a vector of trench fever and typhus was in great part responsible for the collapse and distress of the Serbian armies. On the other fronts, and particularly in Salonika, the mosquitoes, the carriers of malaria, proved a very grave menace to our troops, and the attitude of the average army medical officer towards insects and entomologists underwent a remarkable change from 1916 onwards.

Medical entomology received greater stimulus and greater encouragement during the latter half of the war than it had ever received, and although some of the lessons taught are here and there forgotten—as is shown by the present neglect of the malaria problem in

certain of our colonies and dependencies—the status and facilities for work of the medical entomologist have enormously improved.

It was not in medical entomology alone, however, that the war stimulated the study of insects. Our food supplies were threatened and, in particular, large stores of grain were so rapidly destroyed by such insects as the grain weevils and flour moths that had the war been much longer prolonged these insects might well have become the deciding factor in our victory or defeat.

The war, with its peculiar economic conditions, may be regarded as an exceptional period when the insect menace became acute, but, as Dr. Howard, the former Director of the U.S. Bureau of Entomology, has pointed out, the insect menace, while acute during the war, is rapidly becoming chronic in times of peace. He has suggested that the next big war for civilisation may yet prove to be the war between man and the insect, and even allowing for Dr. Howard's enthusiasm for economic entomology and for his desire to secure appropriations for his wonderful entomological service from hard-headed senators, one has to admit that the menace of insects to our crops and stores is no mere bogey, but is one of the alarming phenomena of our present-day civilisation and trade. To ignore the beneficial changes brought about by the war in the way of improved means of communication and trading facilities and of higher standards of living is no longer possible; but it is equally important that we should try to realise that if man has gained by these advances so has the insect, and that it is steadily entering into competition with man in the vital struggle for food supplies.

From the days of the Pharaohs and the locust plagues of the Scriptures, man has been aware of the capacity of insects for destruction, but nearly always he has been interested in the spectacular, and only

when the insect menace assumed plague dimensions was it given serious attention. Plagues or mass outbreaks of insects such as locusts still occur, as they did in the time of the Pharaohs, but spectacular and destructive as these plagues are, they are to-day less important than the less spectacular and less known ravages of insects which as yet have never received popular or common names—drab, insignificant-looking insects, some of which are not even well known to, or properly described by, the entomologists themselves.

The locusts, with their spectacular migrations and voracious habits, represent only one aspect of the insect menace. The drab coloured grain and flour moths, the dull parti-coloured fruit moth (*Plodia interpunctella*), the dingy grain and rice weevils, the unattractive caterpillars known as cotton boll-worms and cutworms, and the fruit flies (almost unknown except to students of the Order *Diptera*), represent another and even more serious aspect of it. These insects live in or at the expense of our food and clothing supplies just as much as do the locusts, and the losses they cause are in the aggregate of much greater significance in our modern civilisation.

The damage and losses caused by insects belong to two categories. There is the periodic and spectacular destruction caused by such insects as the locusts, and there is the steady concurrent and insidious destruction caused by such obscure insects as the grain weevils and clothes moths which attack our stores, the codling moth, and the fruit flies which attack our food supplies, the cutworms and wireworms, which annually take heavy toll of our agricultural crops, and the powder post beetles which reduce some of our furniture timbers to mere powder.

In endeavouring to assess the extent and importance of the damage caused by insects it is useful to bear these two categories in mind. The destruction

caused by locusts and by such insects as the leaf-eating beetles and by the migratory caterpillars known as "Army Worms," from their habit of marching abreast as they feed, is readily assessed, and bears a fairly close relation to the amount of food eaten by the insects concerned. The destruction caused by grain weevils, clothes moths, and powder post beetles extends far beyond the amount of food or stores actually consumed by them.

In the first case, the amount of food consumed or destroyed represents approximately the loss caused. In the second case, the loss caused can be assessed only after careful investigation of many factors. The common clothes moths of our cupboards and wardrobes serve to illustrate the complex nature of such an investigation. A tiny hole, the size, say, of a threepenny piece, gnawed in a "length" of "material" by a clothes moth caterpillar while the "material" is still on the cutter's table, may be a mere bagatelle involving only a little extra thought or skill for its elimination from the final garment, but a similar small hole gnawed in the exclusive model gowns designed, cut, and finished for the Ascot races is a really serious matter. It means not only the rejection of the garment and the loss of the time and labour expended on it, but if the garment has been "delivered" to some fastidious customer it may result in serious loss of prestige for the firm which supplied it. In such a case the loss involved far exceeds the small amount of material actually consumed by the insect, and the consumption of sixpence worth of cloth may mean the loss of hundreds of pounds.

Because of this question of prestige or reputation the losses caused by insects in the manufacturing industries often attain almost incredible dimensions. It is true that the losses are in a sense artificial, but they have nevertheless to be borne, and are some-

times the only means of making the manufacturer realise his responsibility towards economic entomology. In one important industry in this country the occurrence of many kinds of insects in a staple article of food was wholly ignored until recently by every branch of the industry dealing with the raw product. It was only when the stray and chance occurrence of one of these insects in the finished product offended the taste and appetite of a customer and so brought the prestige of the trade in question that the prevalence and occurrence of the insects in the raw material received serious attention.

In the United States of America, partly as a result of the pure food campaigns, partly because of their tariff regulations, and partly because of their fear of introducing noxious insects into the country, the Federal and State governments insist on rejecting insect infested foodstuffs, but in Britain we are still ignorant that the raw materials of many foodstuffs are infested by insects, and so long as these insects do not appear in the finished product we are happy to remain ignorant.

How long we shall be allowed to continue to ignore the depredations of insects in our foodstuffs and raw materials of industry is uncertain, but the day cannot be long distant when the public at large will be aroused to the extent of the insect menace. In the United States various authorities have published from time to time estimates of the loss caused by insects. In Britain, while occasional attempts have been made to estimate the losses caused by such insects as the blow-fly or sheep maggot and the ox-warble fly, no general estimate of the damage caused by insects to agriculture or forestry or to the manufacturing industries and commerce can readily be made. In America, where vast acreages are devoted to one kind of crop—such as cotton or fruit—and where the timber industry is well organised, it is

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more easy to assess losses and collect information than it is in this country. Again in the United States, because of the introduction of such insects as the Gipsy moth, the Cottony Cushion Scale, and the European Cornborer, insects not native to America and which in their new environment increased prodigiously, threatening important industries, popular interest in insects is easily aroused, and politicians seeking excuse for the imposition of high tariffs or even prohibition of imports have not hesitated to use the introduced insect pest as a means of overcoming opposition to, or of arousing enthusiasm for, their schemes.

In Britain, we, too, have suffered from the introduction of injurious insects, notably from North America, but as these introductions have seriously affected only our forest and timber industries, neither of which looms large in the public eye, they have passed unnoticed. The result is that at present the public and the politician pay little attention to insects. The farmer who annually suffers loss from wireworm in his grass-land accepts the position. The timber importer who inadvertently buys a consignment of wormy timber passes it on if he can, and the loss becomes distributed over the whole industry, and so distributed is less severely felt than it would be if it fell all on one branch of the industry.

Times are changing, however, and the recent history of the relationship of insects to certain branches of the timber industry illustrates a development which is slowly taking place in many industries. In that section of the timber industry which is concerned with the making of furniture, two valuable timbers are ash and oak. Our own supplies of these timbers form only a very small proportion of the total needed by the industry, and the chief source of the major part of the supply is the United States. During the war this source was temporarily closed for lack of

shipping transport. All our ships trading with America were needed to bring us food, and meanwhile the stocks of oak and ash timber in the United States accumulated. Now in these yards the most serious cause of waste in these timbers are certain small beetles of the genus *Lyctus,* known in the American trade as "Powder Post Beetles." These beetles breed in partly seasoned ash and oak, and when, by the accumulation of stocks of the timbers resulting from lack of shipping, their breeding ground was enormously increased, they too increased in numbers. When trade with this country was resumed after the war large supplies of *Lyctus* infested timber were shipped to this country and were distributed throughout our importing yards and furniture factories. Because in the early stages of attack and because during the cold winter months the presence of the *Lyctus* beetle is not easily detected, the full effects of this widespread dispersal of the beetles or their grubs was not realised at first. The importer passed the damaged goods to the merchant, who passed them on to the manufacturer. He in turn passed them on to the furniture retailer, who passed them on to his customers.

In time each stage of the industry began to realise the evil that had befallen it, but the importers, merchants, and manufacturers hoped for the best and although now and then they protested or refused to accept infested timber, the American interests declared that they had no responsibility in the matter. In time, however, the customer rebelled, and his protests, because they affected the prestige of the retailers, gradually became effective and to-day the whole industry is engaged in an effort to eliminate the *Lyctus* beetles as a source of loss and is attaining considerable success.

A similar sequence of events is occurring in other industries, but so long as losses or damage can be

passed by one branch of industry to the next, none of the participants will consider it necessary to take action. So long as the consumer, who is the general public, is ignorant of the state of affairs, insect infestation of our foodstuffs and raw materials will continue unchecked. The losses are borne by the consumer, who pays a slightly larger price for the finished commodity in order that the various branches of industry may recoup themselves for any loss or trouble accruing from the infestation of their raw materials. In one important food industry, one section of it alone—dealing with the produce of only one part of our Empire—spends £20,000 annually in eliminating or reducing insect infestation, and that sum is of course ultimately paid by the consumer in the form of higher prices. Apart from the still higher price paid for insect infested products, the consumer further loses in that very few food products can undergo treatment for the elimination of insects without suffering at least slight deterioration, and the result of insect attacks on our foodstuffs is both to increase their price and lower their quality.

Apart from being sources of loss because of the food or material they consume, or the injury to business prestige they cause, insects may be a source of other forms of loss. Not infrequently the infestation by insects of some imported commodity results in serious delay in marketing, and goods specially despatched from overseas to reach our ports at "the top of the market" may, because of the delay involved in cleaning or sterilising them, "lose the market" and fetch much lower prices than they should have done. If possible this form of loss is also passed on to the consumer in the form of generally higher prices demanded for subsequent consignments or for consignments of lower quality. Not that the consumer is always the defenceless victim of the merchants or that he is deliberately victimised,

but that in all business transactions allowances have to be made for risk of loss, and almost the only means the seller has of making them is to readjust his prices. Not infrequently the overseas producer suffers, and we are only now, and mainly because of the publicity work of the Empire Marketing Board, beginning to realise how big a part insects play, not only in the production of the raw materials of our industries, but also in the marketing of them. In one important branch of Empire trade in which our chief competitors are the Greeks and the Americans, not only are we handicapped by long distance of transport, but that very long distance transport so favours the attacks of insects that if it were not for the subsidy of the industry by Government, the attacks of the insect (the moth *Plodia interpunctella*) would render competitive marketing impossible. In the building up of that young and growing industry the chief difficulty to be overcome is not the climate or cultivation or labour, but a feeble insect.

Insects may not only cause delay or difficulty in marketing, but they may even govern the market itself. In Central Europe, when periodic massed outbreaks of the Nun moth occur in the spruce and pine forests, so much timber is "killed" that it gluts the market and prices fall with a rush.

One of the most interesting aspects of the damage or loss to man and his property by insects is that relatively few of the many thousands of kinds of insects which are known to science are injurious. Of the twenty-three Orders or major groups of insects now recognised by entomologists only seven or eight of them include insects which are injurious and even in these Orders the noxious insects are comprised only in a few families. The zoological or systematic position of an insect offers no indication as to its potentialities as a pest. Such characters as

size, form, and colour bear no relation to the capacity of an insect to inflict injury or cause damage. Most of the really injurious insects are small and inconspicuous, and neither their general nor their detailed or minute structure afford a clue as to their economic importance. The notorious cotton Boll Weevil (*Anthonomus grandis*), which has at times been responsible for the destruction of half the American cotton crop, differs only in minor and structurally unimportant characters from other members of the genus *Anthonomus,* some of which are of no economic importance whatever.

The truth is, of course, that the terms "injurious insect" and "pest" are purely anthropomorphic terms. So long as the cotton Boll Weevil confined its attention to uncultivated wild plants, such as *Hibiscus,* it had no economic significance. It is only because it found ideal and extensive breeding grounds in man's cotton crops and because of man's methods of cultivating cotton over a vast extent of territory that it acquired and assumed its present position as one of the major insect pests of agriculture. The Colorado Beetle (*Leptinotarsa decemlineata*), an insect whose advent in Europe has on more than one occasion created panic among potato growers, was originally a harmless insect living on wild plants of the Order *Solanacæ* in the foothills of the Rocky Mountains. It was not until the westward spread of the American settlers and the extended cultivation of the potato had afforded it a vast and extensive breeding ground that it became an object of interest and serious concern to the agriculturist.

The capacity of an insect to become a "pest" is no vice inherent in the insect itself, but is almost wholly dependent on external circumstances created by man's endeavour to control Nature and wrest from her an ever increasing food supply. The really important factor which decides whether an insect has

the potentialities of a pest is its capacity to reproduce and increase rapidly in numbers under the artificial conditions created by man himself. Many of the insect pests of to-day were, not so very long ago, harmless scavengers, or at most humble plant feeders, playing an orderly part in adjusting the balance of nature; breaking down dead plant or animal remains, serving to check the undue increase of plants in the primeval forest, steppe, or tundra, or of some insect or other animal living in these environments, or serving as the food of some predacious insect or other insectivorous animal.

It is useful to remember this origin of our insect pests, and to note that the Colorado Beetle, the insect whose advent and extremely brief stay at Tilbury some years ago gave rise to our Diseases and Insect Pests Acts, was originally a harmless leaf-eating beetle living on the wild relatives of the potato. Some of the most common pests of our stored food supplies, such as the little Silvanid beetle (*Oryzæphilus surinamensis*) were once, and indeed still are in their wild state, bark dwelling insects usefully serving Nature as harmless scavengers.

The reason why such insects have now come to be designated pests is that they found in the artificial conditions created by agriculture and industry opportunities for their unusually rapid reproduction and increase. It is scarcely necessary to remark that one or two insects in a wheat-field or a granary are of no importance but that hundreds or millions of them are, and one of the main duties of the economic entomologist is to study the increase of insects and the various factors both natural and artificial which promote it. We no longer regard outbreaks or plagues of insects as visitations of Providence. We know that insect pests, however noxious, are not isolated entities with an inherent capacity for destruction, but are part and parcel of a biological complex regulated by

many different factors which can be recognised and investigated.

The more important of these factors may now receive consideration.

CHAPTER III

THE ORIGINS AND CAUSES OF INSECT OUTBREAKS

The investigation of the origins and causes of insect outbreaks is the most important and also the most interesting part of the work of the economic entomologist. It is a part of his work which in the past was sadly neglected, and is even to-day insufficiently appreciated. There are several reasons for the neglect of the study of the causes of insect outbreaks. In the first place their investigation is difficult and time-consuming. Then, faced as he always is with the insistent call for practical control results, the entomologist is tempted to take a short-cut in an endeavour to achieve these, and may consider that he will acquire more credit by relieving a pressing need than by spending time and money in the difficult endeavour to get down to root causes.

The periodic occurrence of insect outbreaks is itself an important cause of the neglect of their proper investigation. Even the most severe insect outbreaks ultimately subside and are forgotten, and it is often extremely difficult for the entomologist to keep up the enthusiasm of his clients or financial supporters in investigating the ecology of an insect whose activities are in abeyance. Frequently some other insect is calling for attention, and it is difficult to disregard it.

Equally important as a reason for the neglect of the fundamental investigation of outbreaks is the general attitude of the farmer, forester, or merchant,

and of the general public. Even to-day their attitude, not much more enlightened, is that of our forefathers, who believed that plagues of insects were visitations of Providence, catastrophies beyond the understanding or control of man. The writer recalls his first meeting with this attitude, and the devastating effect it had on his hopes of obtaining the co-operation of the practical man in an investigation of outbreaks of the oak leaf roller moth (*Tortrix viridana*). During 1920-1924 this pretty moth defoliated the oak woods throughout the whole of the South of England. Its ravages, combined with the attacks of the oak mildew, assumed alarming proportions, and large numbers of valuable oaks were dying in consequence. Practical remedial measures seemed unattainable, and the best way of justifying the writer's position as an official entomologist seemed to be to investigate the progress of the *Tortrix* outbreak, in an endeavour to estimate its possible period of duration and the prospects of its hoped-for early collapse. In the early stages of the work progress was fairly rapid. The habits of the moth were studied, the places where its eggs were laid were discovered to be, not the buds as had been assumed, but the nodes or knots of the young shoots some two or three inches below the terminal buds. The habits of the young caterpillars were watched, and it was ascertained that if they were to survive it was essential on hatching that they should reach the young leaves just as these unfolded from the bud scales. The newly hatched caterpillars could not bore into unopened buds, nor could they successfully attack leaves which had become toughened by a few days' growth or expansion. Parasites of the caterpillars were reared, and the time came when the laboratory had yielded all the results it could, and it became desirable to check these results with events in "the field" or woods. In particular it was thought to be useful to ascertain the variation in intensity of attack which

was observed in different localities. Such information would throw light on some of the causes of this variation, which was thought to be due to the parasitisation of the caterpillars by different kinds of parasitic insects.

Three localities were chosen for this work, and in two of them good progress was made. The foresters were interested in the work and helpful. In the third locality things seemed to hang fire. Consignments of caterpillars required for the study of the intensity of parasitisation failed to arrive, or arrived dead and too shrivelled for study, and finally a diplomatic visit to the locality was made. A long summer day was spent in the stifling leafless woods, and then when the necessary collecting was done the writer sat down with the forester for a tardy meal. The objects of the work were explained, and the difficulty of devising any practical control measures, but this failed to strike any note of understanding or sympathy. Finally the subject was changed, and the suggestion that the broiling dry weather, though unfavourable to tree growth, would be appreciated by visitors to the Ascot races then in progress, immediately brought response from the forester. He explained that there was only one hope of controlling the *Tortrix* plague, and that was to change our hearts and reform our ways. The plague was retribution for our post-war extravagance and levity, such as "bobbed" hair and Sunday motoring. Short skirts had not then "come in," or they, too, would doubtless have accounted for the presence of a few thousand caterpillars! Artificial efforts, said the forester, were bound to be useless and unavailing, and a scientific explanation of the causes of the *Tortrix* plague was evidently to him both wrong and impious.

So extreme a belief in a retributive Providence is not often found nowadays, but, nevertheless, many of the beliefs expressed to-day regarding the causes of

insect outbreaks are only milder forms of it, and, consciously or unconsciously, are derived from it. Sometimes the east wind is held responsible for plagues or blights, as when in late summer swarms of greenfly are observed in our gardens. The greenfly have been there all the time crawling and feeding on our roses and other plants, but, because they remained in compact masses under the leaves or clustered round the stems, were unnoticed. As the summer advanced and the plants become drier and more "woody" nourishment became scarce, a phenomenon hastened by cold, drying winds. These winds, by causing a lowering of temperature, also stimulated the greenfly or aphids to produce winged forms, which then left their impoverished host plants to seek others, and by their apparent sudden appearance gave rise to the belief that an invasion had taken place or that the east winds had produced a blight.

One of the axioms of economic entomology is that, like the poor, injurious insects are always with us, and outbreaks of insects rarely arise by a sudden invasion from some distant quarter, but are the direct result of the steady increase of the ever-present but unobserved few. This may seem improbable to one who is present only when an outbreak is at its height, but the truth of the axiom can readily be demonstrated. It is astonishing how little we observe the numbers of any common insect around us. In a tour of the garden we may with attention observe, say, three or four blue-bottle flies, but if we put down in some spot a piece of raw meat it will soon be covered with these flies in tens and twenties. The short time in which they have assembled shows that they cannot have come from afar, but were present in the immediate vicinity. Examine the piece of meat some hours later, and it will be seething with maggots, which, if undisturbed, will in a few days' time develop into flies, and increase the local popula-

tion a hundredfold. In such a simple experiment we can, by increasing the blue-bottle's food supply or breeding-ground in the form of raw meat, lay the foundation of a blue-bottle outbreak on a small scale. If we continue and extend the experiment we can learn some other important facts concerning insect outbreaks. For the first day or two the blue-bottles will be the only kind of insect on the meat, and they will reproduce and increase in numbers very rapidly. By and by other insects will appear like the big-jawed, black and tawny-grey Cock-tail or Rove Beetle, and the black and orange Burying Beetle. These will eat some of the meat, but they will also attack the Blue-Bottle maggots. Then some tiny, shining, four-winged flies may appear. These are parasites of the Blue-Bottle maggots. Their presence, and that of the Rove and Burying Beetles, slows down the rate of increase of the blue-bottles, partly because there is competition for food between the beetles and the Blue-Bottle maggots, and partly because the beetles and the parasite attack the maggots themselves.

But there are other agencies at work which affect the progress of the developing outbreak we have started.

The Blue-Bottle flies are actively engaged in egg-laying only in warm, sunny weather; cloudy skies and cold winds retard their activities. The rate of growth of their larvæ or maggots is greatest when the temperature is high and slows down in colder weather. Heavy rain disturbs their movements over the meat, and may even drown them. When the Blue-Bottle larvæ are full grown they leave the meat and burrow into the soil, where they pupate enclosed in their skins, which become toughened and barrel-shaped. If the soil under the meat is free and open the burrowing process is easy; if the soil is hard and compact the larvæ may be unable to burrow, and may shelter immediately under the meat or may wander in search

of more open soil. In their wanderings they run the risk of being devoured by predacious beetles or beetle grubs.

If our experiments are delayed until, or prolonged into, late summer a marked slowing down of the development and the rate of increase of all the insects in the community we have established is noticed, until when the frosts become severe activity ceases and all the insects seek winter quarters in the soil or shelter in some protected cranny until spring.

One other point may be noticed in our experiment, namely, that in warm, dry weather, and especially under a hot sun, the meat we supply becomes dried and shrivelled and ceases to attract the Blue-Bottles, and becomes unpalatable to their larvæ, which wander off or succumb to the scorching heat. Incidentally they dislike strong light and are negatively phototropic.

If, now, we review our observations we find that several agencies govern the rate of increase of the Blue-Bottles. The weather or climatic conditions in which temperature, humidity, and light are separable as distinct factors, affect both the insects and their food. The food itself is important. If it is withheld the Blue-Bottles must go elsewhere or starve, and their larvæ, if only partly grown, usually starve, even though some become cannibal, eating their more impoverished or dying associates. The predaceous beetles and parasites also play a decisive part in regulating the Blue-Bottles' numbers, and finally the soil conditions affect the well-being of the Blue-Bottle community by affording a suitable or unsuitable medium in which the maggots may undergo the critical period of their final metamorphosis or pupation.

Now these factors—climate, food supply, natural enemies, such as predators, and parasites, and soil conditions—whose effects we have traced in our experiment, are the chief factors which regulate the increase in numbers of all insects. They act in this

respect both directly and indirectly, and interact among themselves. The climatic conditions act not only directly on the insect itself, but if it be a plant-eating insect they act on it indirectly by regulating the growth of the plant, which is its food supply. The study of this combination and interaction of these primary factors is one of the most fascinating branches of economic entomology. It is now honoured with a name to itself and is described as insect ecology or "autecology." The term ecology is applied when one studies the association of insects in some particular type of environment or "plant association," such as a damp oak wood, or a chalk pasture, and autecology if one studies the plants and animals associated with some particular insect.

If we are to understand the insect pest we must know something of its environment, and to learn something of that it is useful to consider the factors which constitute or produce that environment. They are the same factors which we discovered in our experiments with the Blue-Bottle flies and the meat, which were really a lesson in the autecology of the Blue-Bottle fly (*Calliphora erythrocephala*). If we consider each of these factors or agencies in relation to insects in general we are in a fair way to appreciate the nature of the origins and causes of insect outbreaks.

Climate affects insects, in general, by determining their geographical distribution, and, in particular, by regulating their rates of development and increase. The components of the climatic factor are temperature, humidity, and light.

Temperature affects insects by increasing or decreasing the rate of their metabolism. At low temperatures insects are less active, consume less food, moult less frequently, and grow more slowly. Below and above certain temperatures they cease to be active and become comatose, and extreme temperatures at either end

of the range cause death. This range varies from different kinds or species of insects, but in general it extends from 15° to 65° Centigrade. Sudden considerable changes in temperature may be fatal to insects, and Professor Bachmetjew has shown that insects are capable of surviving very low temperatures if these come on gradually or if thawing takes place gradually. An extreme fall of temperature, followed by a rise and then another fall, even although the second fall is less severe than the first, is almost always fatal. It is for this reason that insects, such as the common humble bee, can survive the extreme cold of winter, but frequently succumb to relatively mild spring frosts.

The temperature by regulating the rate of insect metabolism and development also regulates its rate of increase. Thus in the valleys of Switzerland the common cockchafer undergoes its development from the egg to the perfect insect in three years, but on the higher lands and foothills of the Alps it requires four or even five years. The reason is that the feeding and growing seasons are shorter at the lower temperatures of the highlands and the insect requires a longer period in which to attain full development. The effect of the longer period of development on the cockchafers numbers is marked, for in warmer localities it is so numerous as to be a veritable pest, but in colder districts its numbers are so few that the damage it causes is negligible. An Austrian entomologist named Zweigelt has mapped out the distribution of the cockchafer in certain parts of Europe, and has shown that while in districts having a mean annual temperature of 7° C. and over, it is seriously harmful, in districts in which the temperature is below that figure it is negligible as a pest. In this country the chafer is most harmful in the South of England, but as we go north it becomes less common and less abundant, until north of the Forth it occurs only

rarely, and is of no importance as a pest of agriculture. As with the cockchafer, so with other insects, their occurrence and numerical abundance is regulated by the temperature.

Humidity or the amount of moisture in the atmosphere affects insects much in the same way as temperature, but its effects are less extreme and in practice, because it is almost impossible for changes in humidity to occur without a change in temperature following and *vice versa,* it is necessary to consider the two factors, temperature and humidity, together. In so far as it is possible to separate the two factors, it appears that very high or very low humidities, combined with high temperatures, are fatal to insects. At very low temperatures humidity is low because of the freezing of water, and it is difficult to decide which factor, low temperature or low humidity, is the more potent in affecting the insects studied.

At the same temperature certain humidities are more favourable to some insects than to others, and in general insects thrive best in atmospheres of moderately high humidity. The rate of growth of bacon beetle larvæ, for instance, may be three times as rapid in an atmosphere of 80 per cent. humidity as in an atmosphere of only 40 per cent. humidity.

The effect of light upon insect increase has been but little studied, and it seems probable that it is more important in deciding the habitat selected by the insect and so indirectly influencing its numbers than in affecting them directly. Many insects are negatively phototropic, shunning the light and living and thriving only in dark places, but the investigation of the effects of light on insects is difficult, partly because we have as yet no satisfactory method of recording variations of light intensity in the field, and partly because the reactions of many insects to light varies with the different phases of their development and with the sex of the individual.

Temperature and humidity acting directly on an insect constitute one of the most important factors governing its rate of increase and numbers, but the indirect effects of temperature and humidity are also important.

The effect of hot sun and dry weather in drying up the Blue-Bottles' food supply is just as potent a factor in retarding their increase as are the predators and parasites. So, too, such extremes of climate as droughts and floods, by killing the fine root hairs of plants, reduce their vitality, afford entrance for fungus diseases, and predispose the plants to attack by insects which are unable to attack the vigorous, healthy plants.

Drought and floods are now recognised as the frequent predisposing causes of outbreaks of many forest insects, such as the bark beetles and wood-boring beetles. In the London district in 1921 the drought, by lowering the vitality of the elm-trees, led to an epidemic of bark-beetle attacks, which in some of the public parks killed off many trees.

There is some evidence to show that climatic factors acting through the plant determine the production of winged forms of the greenfly or aphides living on the plant affected, and the indirect action of the climatic factors is almost as potent as their direct action on insects' increase.

The amount of food available to an insect is naturally a vital matter in relation to that insect's development and increase, and it is by increasing the food supply artificially that man himself creates the majority of his insect problems. The growing of crops in large but compact areas and the cultivation of pure crops of only one plant are wholly artificial phenomena. They afford the insect an uninterrupted and large supply of its host plant, and thereby favour its increase.

An insect living on wild Solanaceæ finds its host

plants scattered and mixed with plants which have no interest for it, but the same insect arriving in a potato field finds an unlimited and uninterrupted food supply. When its numbers increase, dispersal is no longer necessary to insure adequate feeding or breeding-ground. The risks which such a dispersal, necessary when the insect is living in a natural environment, entails are avoided in the potato field, and by the mere act of cultivating his crops as pure crops extending over large areas, man favours insect attacks on these crops. The extension of the cotton-growing belt in America resulted in an extension of the area of distribution of the cotton Boll Weevil, until that insect now extends over nearly half a continent, and it probably travelled largely by its own exertions through the ever-extending cotton-fields.

The storage of large quantities of such products as grain and timber in our wharves and warehouses is itself a direct cause of damage to these products by the insects which live in them. The menace of the grain weevils to our wheat stores in the war, a menace so alarming that it led to the appointment of a special committee of the Royal Society to consider and combat it, was the direct result of the concentration of the grain in large stores. The grain weevils found themselves with an unlimited supply of food and breeding-ground in which they could breed almost undisturbed. The docks and wharves at our ports constitute a constant breeding-ground for the insect pests of stored products simply because they afford a concentration of food material.

The extraordinary increase during the war of the louse, already mentioned, was the result of the concentration of large numbers of human beings in camps and barracks, combined with lack of adequate facilities for washing and for the practice of normal hygiene. In civil life the strongholds of the louse are overcrowded slums and "doss-houses."

By artificially increasing and storing their food supplies man is constantly favouring his insect enemies. Fortunately for him, there are other factors affecting their increase, and of these other factors the insects' natural enemies have of late years received special attention.

If we collect in the field any considerable number of caterpillars of some common moth and rear these in the house or the laboratory, we shall find that instead of rearing a moth for every caterpillar collected we shall rear only a proportion of moths, while in our breeding cages a number of other insects not knowingly introduced into them will appear. These are the two-winged *Tachinid* flies and the four-winged *Ichneumonid, Chalcid* or *Braconid* wasps. All are parasitic on the caterpillars, and their eggs or larvæ were present within or on the caterpillars when these were collected. Or it may happen that our caterpillars "wilt" and die off, and in such an event we are probably dealing with some bacterial, protozoal, or fungus disease.

These two groups of insect enemies, the parasites and epidemic diseases, are probably very important checks on insect increase. In the field we may observe many birds feeding on insects. The fly-catchers, the martins and swallows and the little tom-tits are known to most people as insect eaters. Then many mammals such as the mole, the shrews, and the hedgehog are known as insect eaters. So, too, are frogs, toads, lizards, and fishes. Spiders are largely insectivorous. Unfortunately our knowledge of the real part played by these groups in keeping insects in check is by no means precise. With regard to birds, despite the investigations of workers in America, on the Continent, and at home, we are still ignorant as to the insect food of birds, and all that can be said definitely at present is that during the nesting season many birds themselves consume, or feed to their nestlings, enormous

numbers of insects, and that fuller investigation of the food of nestling birds is much to be desired.

If our knowledge of the insect food of birds is deficient, that of the insect food of mammals, reptiles, batrachians, and fishes is even more meagre. It is even doubtful whether insects form an appreciable part of the food of some of those mammals which we call insectivores. As a zoological term in classification the name is useful, but as descriptive of the mammals' food it may almost be a misnomer. In this branch of natural history there is much work to be done. As Mr. Elton has so well pointed out in his charming and excellent book on *Animal Ecology,* accurate observations and proper recording of observations made in the field are still far too rare even among professed naturalists. With mammals, reptiles, batrachians, and fishes, as with birds, all we can say at present is that they play some part in checking insects, but to say how important that part is requires much fuller and more accurate investigation than has so far been given to the subject.

In point of numbers the insect enemies of insects are enormously in excess of the vertebrates, but in spite of this our knowledge of the relationship of predaceous and parasitic insects to their insect hosts is both fuller and more exact than our knowledge of birds and mammals which prey on insects; this, too, in spite of the minute size and concealed habits of parasitic insects. In fact, the subject has become so extensive and its study so specialised that it forms almost a distinct branch of economic entomology, and both in America and Europe special "parasite" research stations have been founded for its proper investigation.

A general account and discussion of insect predators and parasites has been given by Professor Balfour-Browne in his *Insects,* published in this library, and readers should refer to it. Meanwhile our concern is with the part played by insect parasites

and predators in checking or controlling outbreaks of injurious insects. In this regard the parasitic insects so far appear to be more important than the predators. While it is true that as a rule the individual predaceous insect destroys more insects than the individual parasites, the rate of reproduction and increase of these larger predators is as a rule slower than that of the parasitic insects and also than that of the host insect. The food of the predaceous insect is, too, more varied, and for this reason it is more difficult to assess the real value of the predator as a check on a particular pest. The tendency has been, therefore, to attach more importance to parasitic insects as checks on insect pests, and, because they are more numerous in species than the predators and more easily studied, we have more published information concerning them.

A parasitic insect may restrict itself to a particular species of host, or it may attack several species of host insects. In the first case it is said to be a specific parasite; in the second a polyphagous parasite. It may attack the host insect at only one stage in that creature's development, and so we recognise egg parasites, larval parasites, and pupal parasites. In one country or in certain circumstances a parasite may be an egg parasite; in another country or in different circumstances it may be a larval parasite. All these points have an important bearing on the relationship of parasitic insects to their hosts. It has been found, for example, that many insects are held in check only when the insects parasitic on all their stages of development are present. This is the basis of the American "parasite sequence" theory, which postulates that an injurious insect is kept under control only when all the parasites attacking each different stage of its development are present and active in the area or district affected. One most interesting aspect of this "parasite sequence" is that the sequence of parasites of the Gipsy moth, for example, comprises in Japan a

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different series of parasites from the Gipsy moth sequence in Europe, while in the United States of America a third type of parasite sequence is evolving at the present time as a result of the introduction of Gipsy moth parasites there from Japan and from Europe.

If in any district or season the parasite sequence of some insect is for any reason incomplete, the result is the rapid increase in numbers of that insect. It may be that a parasite of the egg stage is not present in its usual numbers or is even altogether absent and that in consequence more of the host insects survive and reproduce, and a knowledge of the sequence of parasites of an injurious insect is essential to the proper understanding of its numerical status and potentiality.

Formerly it was considered that only the specific or monophagous parasites of an insect were effective in keeping its numbers in check. It was supposed that a parasite which had many hosts dissipated its energies and had no marked effect on the rate of increase of any of its hosts. This view is now recognised as a narrow if not an erroneous one. If a parasite is restricted to a single species of host insect, it is obviously dependent on that insect for its continued existence. If it killed out its host it would die out with it, and its only hope of survival must lie in some correlation between its rate of development and increase and that of its host. Its numbers as compared with those of its host may vary from year to year, but they can vary only within such narrow limits as will insure the survival of the host insect.

Much more interesting and more effective as regulating the numbers of an injurious insect are the polyphagous parasites, which attack and breed in more than one species of insect. These parasites may attack a wide range of hosts and they are for that reason more or less independent of any particular one of their hosts. Unfortunately we know as yet very little regarding their ecology. We know that in some

cases their presence and abundance in any locality vary with the richness of the insect fauna of the locality and that the insect fauna varies with the richness of the flora. In a few instances we can correlate their scarcity or abundance with the poverty or richness of the flora, but the study of the complete ecology of even one polyphagous parasite is a long business requiring several years for its completion. Meanwhile the important part played by the polyphagous parasites in regulating the number of an insect pest is being more fully recognised, and before long the ecology of at least some of the polyphagous parasites of such injurious insects as the Nun moth, the Spruce Budworm, the Oak Tortrix moth, and the Codling moth will probably be worked out fairly well. The ecology of these parasites is extraordinarily complex. Certain parasites of the Oak Tortrix moth—*Tortrix viridana,* for example—have as many as twelve alternate hosts, and these hosts feed on no less than twenty-three species of host plants ranging from such forest herbs as the wood sage (*Teucrium Scorodonia*) to shrubs like guelder rose and hawthorn and to trees like birch and sweet chestnut. The absence of any one of these host plants in a locality may therefore affect the numbers of the polyphagous parasite in that locality and through it the numbers of the Oak Tortrix moth.

It is known that variations in the composition of the forest flora affect the abundance of such forest pests as the Nun moth and the Spruce Budworm. In certain districts in Sweden, where because of the poorer soil the forests are composed of many small, slowly growing trees, the area and light available for other plants is limited, and in these districts the Nun moth is more plentiful than in other districts where the soil is richer, the trees are more widely spaced, and the forest flora is richer.

The comparative freedom of the western forest

areas of Canada from severe outbreaks of the Spruce Budworm has been ascribed to their richer composition. The western forests comprise many species of forest trees, hemlocks, cedars (not true cedars, but species of Thuja), balsam firs, and Douglas fir. So far they have been less ruthlessly exploited than the eastern forests, and these two factors, combined with higher rainfall, cause their flora to be more varied and richer than that of the eastern forests. In the east the forests, formerly consisting of pines, spruce, and balsam firs, were first reduced to forests of spruce and balsam because of the lumberman's exploitation of the pines, of which the white pine was the most valuable. Now the demand for spruce for paper pulp manufacture is rapidly reducing the spruce-balsam forests to forests of pure balsam. The balsam fir is probably the original host of the spruce budworm, and in any case it is the host which best suits that insect; and the higher the proportion of balsam fir in the forest, the higher the risk of spruce budworm outbreaks. Equally important, however, is the change in the flora which has taken, and is taking, place in the eastern Canadian forests. Just what the change is has not been adequately investigated, but there is little doubt that one of the parasites of the budworm, a braconid wasp of the genus *Phytodietus,* is adversely affected by that change, and until more detailed studies of the flora of these eastern forests have been made, the full extent of one of the main causes of budworm outbreaks cannot be properly assessed.

Apart from the question of the local flora and its effect on the parasites of any insect pest, yet another complication arises.

"Big fleas have little fleas upon their backs to bite 'em,
And little fleas have lesser fleas, and so *ad infinitum*,"

and parasites of insects also have their parasites, which we call hyper-parasites. These have also to be taken note of in our study of insect ecology. Moreover, an injurious insect may be attacked by more than one parasite at a time, and this super-parasitism, as it is called, has a marked effect on the fate both of the parasites and the insect pest. While in the year of its occurrence super-parasitism adversely affects the host insect, in subsequent years its effect may actually be to favour it by reducing the parasites' numbers. This happens when, because of the presence of the super-parasite, the first coming or primary parasite fails to reach maturity for lack of food, which it has to share with the super-parasite. Hyper-parasitism may be even more effective in favouring the host insects, and the phenomena of hyper-parasitism and super-parasitism are of the highest importance in relation to the rate of increase of an insect pest.

Because of the extraordinary complexity of insect ecology, we are still far from being able, except in rare instances, to assess which are the primary causes of insect outbreaks. We can, as the plant ecologists have done, classify the types of the main factors affecting the occurrence and prevalence of insects in any locality or environment. These factors are the same for insects as for plants—the climatic factor, the biotic factor (*e.g.*, predators and parasites) and the edaphic or soil factor. In entomology, however, the soil factor is less important than it is in botany, because its direct effects are limited and in general affect only such insects as live actually within the soil. On the other hand, the soil conditions, by acting through the host plant of the insect or, as we have seen, by affecting the actual composition of the insect fauna in a locality, are none the less an indirect factor of considerable weight. At present this study of insect ecology is still somewhat neglected by entomologists,

but it is gradually receiving attention, and one of the important advances recently made in the organisation of the Parasite Research Station of our Bureau of Entomology is the appointment of a plant ecologist who will be able to advise the Station on the botanical environment of any insect and assist in unravelling the many complexities which the proper study of an insect and its parasites present.

This closer linking up of entomology with botany is all to the good. As we shall see later, entomology is also linking up with chemistry and physics, and while the study of the insect as an insect must always be the basis of the entomologist's training and knowledge, narrow specialisation, formerly the chief barrier to the progress of economic entomology, is gradually giving way before the advance of a wider and more catholic study of insect biology and of the relationship of the insect to its environment.

Of the control of insect outbreaks by bacterial, protozoal, or fungus diseases our knowledge is still somewhat scanty. Various diseases which attack insects are known and have been and are being studied, but of the real part which they play in checking outbreaks of insects our knowledge is vague. Outbreaks of such insects as the locusts, the Nun moth and other Lepidoptera, the Sawflies, and certain weevils, are brought to an end by bacterial and fungus diseases; such half-domestic insects as the honey bee and the silkworm suffer from bacterial and protozoal diseases, but the extent to which such diseases occur in Nature is not readily determined, and until the bacteriologist, the protozoologist, and the mycologist specialise on insect diseases, knowledge of these is bound to be attained slowly. With the vast fields of medical and veterinary and plant pathology open to them, the mycologists, protozoologists, and bacteriologists are unlikely to devote their attention to insect pathology, which requires for its proper study a special technique and a

knowledge of insect physiology that even the entomologists themselves do not possess at present.

The major difficulty in the investigation of the relationship of insect diseases to the variation in an insect's numbers is that, while these diseases can readily be studied and the organisms causing them readily be cultivated in the laboratory, experimental work on a large scale in the field has so far resulted in failure. This has given rise to the opinion widely held by entomologists and by mycologists that insect diseases such as are caused by fungi cannot be used artificially to check insect outbreaks. That opinion is correct only in so far as our present knowledge of insect pathology can take us, but it really means that our knowledge of the technical methods of exploiting insect diseases is inadequate. Doubtless with increased knowledge of insect physiology and insect pathology the time will come when bacterial, protozoal, and fungus diseases of insects will be used in the control of insect outbreaks just as the parasitic insects are used to-day.

Meanwhile we know that various kinds of epidemic diseases exist among insects under natural or wild conditions and that they play a considerable part in regulating insect numbers.

CHAPTER IV

THE BIOLOGICAL BASIS OF INSECT CONTROL

Although a knowledge of the factors governing the increase of insects and the rise of insect outbreaks should form the basis of all measures designed to control or prevent the rise of outbreaks, in practice these

control measures are still applied on a more or less empirical basis. The reason for this is that in practice the need for some immediate remedy is usually too urgent to admit of a prolonged or systematic investigation of all the aspects of the outbreaks of the injurious insect responsible and that it is always difficult for the entomologist to secure financial support for the investigation of an insect when its injurious activities are in abeyance.

The result is that many of the control measures in use to-day are merely palliative measures originally designed to remedy matters during some exceptionally severe outbreak. Insecticides as a class are palliative measures bringing about a more or less rapid decrease of the insect during the first or second seasons of its abundance. Mechanical measures, such as fly-traps, grease bands placed round trees to entrap wingless moths or wandering caterpillars, or bait traps designed to attract moths, weevils, and "wireworms," are also still largely employed merely as palliative measures designed to secure relief during severe attacks.

More fundamental in their application are the control measures termed "cultural and parasite controls." Cultural measures are those which are brought into application by the modification of cultural practice, as when resistant or immune varieties or strains of a crop are substituted for less resistant varieties; or when the early or the late sowing of a crop is practised to evade the attacks of such insects as the turnip flea, beetles, and the frit fly of cereals. These are measures which may become part of routine practice and are more or less permanent in their effects. Parasite control is the term used to describe the breeding and release of the parasites of an insect pest in order to reduce its numbers more or less permanently. At present the use of parasite control is almost confined to insect pests which have been accidentally intro-

duced into a new area or country where, freed from their natural enemies which kept them down in their native land, they have become serious pests.

These two types of control measures—cultural and parasite—require, even for moderate success in application, a fuller knowledge of the ecology of the insect pest than do mechanical and chemical or physical control measures, and in particular the development and increased vogue of parasite control has called attention to the neglect of insect ecology in the application of control measures generally. For this reason we may consider parasite control first and see how a knowledge of the factors governing the increase in numbers of an insect is useful in that form of control and then how it may be equally useful in the application of other methods of control.

The control of an insect by breeding and setting free its parasites against it has in certain instances proved extraordinarily successful. In nearly all these instances, the insect to be controlled has been an introduced insect in the country concerned, and the causes of its undue abundance and increase have been an ample food supply, a favourable climate, and an almost total absence of its natural enemies. The food supply has been the staple crop or one of the staple crops of the country, and as a rule a crop which has been increasingly cultivated. For that reason no reduction in the food supply and breeding ground of the insect has been possible or even conceivable. The climatic factor is beyond man's control, and the obvious method of control, other than the use of insecticides, which the vast areas over which the insect attacks occurred precluded, has been that of introducing into the country a parasite or a predator, or several parasites and predators, which are known to attack the insect in its country, or countries, of origin. Briefly, the position has been that the insect has arrived in a new country leaving its natural

enemies behind, and the method of controlling it has been to send its enemies after it.

The most striking successes with this method are the control of the Cottony Cushion Scale in California by the introduction from Australia of the ladybird beetle *Novius* (*Vedalia*) *cardinalis,* and the control of the sugar-cane leaf-hopper and other insects in Hawaii by the introduction of various parasites and predators. These successes have created a vogue in parasite control, and nearly every country has now in its employ, or acting as collectors for it, entomologists skilled in the search for likely parasites of important insect pests. One of the functions of the Parasite Laboratory of the British Imperial Bureau of Entomology is to collect and rear parasites of insect pests required by the Dominions and Colonies, and although this station has been in existence only three years it has already despatched thousands of parasites and has difficulty in coping with the ever-increasing demand for more.

It must not be assumed that the collection and rearing of parasites for insect control is a relatively easy business. On the contrary, it is a much more complex task than even some entomologists realise, because so many different factors must be taken into consideration in deciding on what parasites to send, when best to send them, and how to send them. It must, in fact, be admitted that some of the early successes in parasite introduction were largely fortuitous, and we realise to-day that the chances of successful introduction are not always good, but that on the contrary failures must be frequent.

In the first place, before selecting a parasite to be sent to a new country it is necessary to insure that it is a parasite of the insect to be combated and not a hyper-parasite living on some primary parasite which has been overlooked. Again, it is essential to avoid sending out two parasites which may behave as super-

parasites and thus cancel one another out, so to speak. Then it is necessary to ascertain whether the parasite selected is likely to be attacked by hyper-parasites or be joined by super-parasites in the new country. This is information which is often most difficult to obtain.

Still other precautions must be taken, as, for instance, whether, in the new country, the parasite may not find some new host, quite other than its intended host—the pest—which it may prefer so well as to ignore the pest host altogether. It is also necessary to ascertain whether any insects other than the pest host may serve as alternate hosts for the introduced parasite and so enable it to carry on in times when the pest host is few in numbers. Sometimes, as we have seen, not one parasite or predator but a sequence or chain of them may be necessary to check same major pest, and here is yet another difficulty: to find, collect, and despatch such a sequence of natural enemies.

In the early parasite introductions many of these points were not recognised as vital for success, and even to-day are ignored in the hope that some of the parasites introduced may prove successful. In practical control work such "hit and miss" methods may be necessary where losses are serious and action is urgent, but the methods are not to be recommended. One grave danger of parasite or predator introduction is that the parasite or predator introduced may in the new country become injurious, either by becoming itself an enemy of the host crop or by becoming a hyper-parasite of some existing host parasite, and "hit and miss" methods of introduction allow of no safeguarding against these contingencies.

The complexity of the problems existing in successful parasite introduction are now recognised by the leading exponents of the method, and the days when the introduction of some parasite found by chance was considered satisfactory are over. The results of

parasite introduction, even when it appears successful, are receiving close scrutiny and, thanks to the work of such eminent experts in parasite control as Dr. W. R. Thompson, the head of the Farnham Royal Parasite Station, and of his former colleague and assistant, Dr. Parker, haphazard methods of parasite introduction and hasty optimism in assessing its results are now regarded with suspicion as unscientific and doubtfully valuable. Sound control work by the introduction of parasites is achieved only after patient and prolonged investigation of every aspect of the problems to be solved, and even when all the information so obtained enables the entomologist to select and secure the desirable parasite and promises reasonable hope of success there still remains the delicate and difficult matter of shipping or despatching the parasite or parasites selected and reared.

Obviously, the parasites must be shipped alive and must arrive in a healthy condition. They may be despatched to be released against the pest immediately on their arrival or they may be despatched in a stage where further rearing of them is necessary after their arrival. In some cases it may be necessary to keep the parasites in quarantine after their arrival in order to obtain definite information as to their behaviour in their new habitat. To insure success in parasite introduction every care must be taken to insure the well-being of the parasite during its voyage, on its arrival, and after its arrival. The conveyance of the parasites in cold storage affords a ready method of preventing the insects' development during the voyage, but at present we do not know enough about the effect of prolonged subjection to cold on insects to feel sure that this method is innocuous. Even if it be innocuous, the method has certain drawbacks, because it is not always possible to insure a gradual change from cold storage to normal temperatures on the arrival of the insect, and shocks such

as are produced by sudden changes of temperature may prove fatal. In the writer's experience, a batch of parasites was shipped in cold storage from London to Montreal and presumably reached that port safe and sound; from Montreal to Princeton, however, the batch was stored in a heated van, and it was no wonder that when the batch was examined the majority of the parasites were dead, and the rest died soon afterwards.

The study of this question of the shipment of parasites now forms quite a special part of the entomologist's work in a parasite laboratory or station, and soon we may hope to obtain safe and satisfactory methods of shipment applicable to different means of transport and transfer from cold to warm countries, and *vice versa*.

If despite all its difficulties the introduction of a parasite to a new area has been accomplished, the next question is to ascertain how far the parasite is effective in checking the insect pest. The usual test is to collect numbers of the pest insect in the year following the release of the parasite and for several years after. If the pest insects collected yield a number of parasites, and if in subsequent years this number becomes higher, then the parasite is said to be well established. Sometimes, however, the parasite may not be found or, in technical parlance, "recovered" for several years after its release. In this case its establishment is slow and doubtful. The "recovery" of the parasite is not always a criterion of success. Sometimes the parasite so laboriously introduced is already, unknown to the local entomologist, represented in the area by a few individuals. It has been related how in one instance a negligent laboratory assistant, having allowed a batch of newly arrived parasites to die, "released" their corpses. This satisfied his turbid conscience, but it led to an amusing error. The parasites were duly recorded as

"released." Next year they were recovered, and this so astonished the assistant that he confessed his negligence, and so enabled his chief to learn that the parasite he was trying to establish was already present on the area and that the supposed "recovered" parasites were really indigenous ones whose presence had been overlooked.

Accidents of this kind emphasise the need for very careful assessment of the actual status of the introduced parasite and of its effectiveness in control. A drop or decrease in the numbers of the insect pest or a marked reduction of its ravages may have no relationship at all to the introduced parasite. It may be that the weather conditions have checked the pest in its early stages or that some disease has attacked these. It may even be that for some reason still obscure the ratio of increase of the pest has fallen. Such a fall in rate of reproduction does take place in insects.

How, then, are we to assess the success of parasite introduction? Only by careful collection of the parasite by collecting and rearing numbers of the pest, and by keeping record of the numbers of the pest over a sample area of the crop or, better, over several sample areas or sample plots. By observations on these plots, carefully recorded, a fairly true account of the status of the pest and the parasite and of the relationship of the two can be obtained. When that has been done, and if the results are favourable, the "parasite introduction" is complete and has been successful. If the introduction has been successful and the numbers of the pest have fallen and keep falling, or remain low, over a period of years control has been attained.

The next thing is to estimate its value, having regard first to the loss prevented and second to the cost of applying the control. It is unfortunate that in Government departments and in most businesses the

accountants will insist in writing down the losses caused by insects for the year in which they occur, and will insist on charging to the same year's accounts the whole cost of control measures. The system is doubtless sound, but it is desperately unfair to the entomologist because the effect of it is to make his costs look absurdly high. Let us assume that the entomologist has successfully controlled a serious pest of an important crop. His experimental work, let us assume, has been done in one particular district and has extended over five years. Now to charge the cost of that work to that particular district and to the costs of these particular years is wrong, in that it produces a distorted account of the value of the work. It is time that Government departments and others judged scientific work by its value and not by its cost. However, the point to be emphasised is that successful control work done in one district will apply to all districts where similar conditions prevail, and not only to all districts but to all countries, and to assess its value on the basis of its cost is absurd. Such a principle is not applied in industrial chemistry or industrial engineering, but curiously enough, it is applied in industrial entomology. A chief reason for it is that the entomologist himself is rather shy of incurring costs, he has still some of the modesty of the shy be-spectacled butterfly hunter of the *Punch* cartoonist sticking to him, and is far too prone to be unduly pleased when the lay public or the administrative officials consent to view his collections or parade his laboratories.

In actual fact, the cost of equipping and maintaining an entomological station and staff is extraordinarily low compared with the cost of a chemical or physical or engineering laboratory, and the control of insect pests by means of parasites, as by other forms of biological control to be referred to later, is cheaper than to control them by the use of insecti-

cides, always assuming that the same standards of work and the same standards of assessment of results apply to both methods. We shall return to that point later, meanwhile it may be repeated that to judge the value of a new control method by its cost in one particular district is wrong, because the method once devised is available for all time and for all countries, and, always assuming that it is really effective, gives benefit, not for the year in which it is first applied, but for subsequent years also. On such a principle of assessment the control of insect pests by the method of parasite introduction is in certain definite circumstances a valuable and practicable method. The definite circumstances are that the insect pest in question is an introduced or exotic one, is comparatively free from parasites, and that the crop which it destroys is a staple and valuable one.

The control of injurious insects by their parasites under other circumstances has still to be tried out. By many entomologists it is considered that where an injurious insect is native in or indigeneous to a locality, and when it has a number of parasites attacking it, then the artificial encouragement of these parasites is impracticable. The contention is that the parasites are already pulling their full weight and any increase of their numbers by artificial means, such as the introduction of numbers of parasites from some other locality, can be only temporary in its effects. This contention is not easily refuted at present, because of the lack of accurate information, even in the case of our major pests, regarding the extent of their parasitisation from year to year and from district to district; regarding the relationship of weather conditions, first, to the pest itself and to its parasite and their effects on the relationship of the two insects; regarding the importance of variations in the flora, and other fauna of the locality, and finally, which is the more to be deplored, regarding the relationship

of agricultural or commercial practice to the pest and its parasite. It has been suggested that we do not even have actual data to support the hypothesis that the numbers of an insect and its parasites do bear any close relationship to one another. This last suggestion, it is only fair to say, has been put forward by one of the strongest and most authoritative advocates of parasite control, and rather with the intention of emphasising the need for acquiring information and data on these matters than with the intent to disparage the hypothesis.

At present the control of insects by encouraging their natural enemies in their native habitat has been practised only in the form of bird protection, and even this has been carried out more by bird lovers seeking some practical support for their hobby than by entomologists engaged in combating some particular insect pest. The encouragement of birds such as tits and warblers is undoubtedly to be approved by the entomologist, but the recently promulgated hypothesis of "territory" in bird life* raises the question as to how far the numbers of any bird species can be increased within a limited area. If the "territory" hypothesis means that each bird or pair of birds is jealous of its particular territory to the exclusion of others of its kindred, then evidently the increase in the numbers of these birds in a locality will be governed by the extent of the territory occupied by each pair and limited accordingly.

Further progress in the study of the relationship of birds to insect numbers is dependent as much on the ornithologist as on the entomologist, and will be most rapid when these two biologists co-operate. Meanwhile, the entomologist is more likely to advance his knowledge of the insect enemies of insects, and

* See Mr. E. M. Nicholson's volume *The Study of Birds,* in this Library.

the lines along which progress will be made are already fairly evident.

The steadily increasing value of our crops and stores, the tendency towards the cultivation of larger and larger areas of crops of one kind, the storage of larger masses of grain and other foodstuffs and of the raw materials of commerce, and the generally increasing interest of the public in insect problems, all favour the search for new and more enduring methods of checking losses caused by insects, and the success and romance of the control of insect pests attained notably by the Hawaiian sugar-cane growers has tended to call attention to the value of ecological work. Added to these factors is an increasing dissatisfaction with the empirical use of insecticides and a realisation of our present ignorance regarding their modes of action. Ecological work is therefore becoming more sure of sympathetic consideration and financial support by administrators and agriculturists alike.

In forest entomology, the ecological study of insects is already well advanced. The reasons for this are that cultural control measures, such as the rotation of crops, are not possible in forestry, because the crop takes at least thirty or forty years to mature and may take even a hundred years or more. The extent and height of the forest crop precludes the use of insecticides except when applied by aeroplane—a method still to be developed and perfected—and, finally, the forest entomologist has always been, since the days of Ratzeburg, the father of forest entomology, an enthusiastic field worker. Forest crops covering, as they do, large areas, offer more uniformly extensive habitats or biotic associations than do agricultural crops, habitats that change more slowly than those created or produced by agriculture and which therefore lend themselves more readily to study and classification. By the very nature of his work the

enthusiastic forest entomologist becomes ecologically minded. The long duration of the crop, the long-deferred financial returns, and even the awe and austerity of the forests themselves favour the longer view and the more philosophical outlook required for the study of fundamental principles. It is not surprising therefore to find that the best account of the principles of the biological control of insects is to be found in the literature of forest entomology, and that our outstanding European forest entomologist, Professor Escherich, of Munich, is a strong advocate of ecological investigation.

Briefly, the lines along which forest entomology is developing are the lines along which agricultural entomology will follow. An examination of recent forest entomological literature shows that more and more attention is being paid to the behaviour of insects in the field, and in particular to the causes of their variation or fluctuation in numbers. The effects of familiar forest operations—such as thinning—on the increase of insects are being studied, the effect which the removal of the brushwood or slash (tops and branches of felled trees too small or unshapely to be used as timber) has on bark beetle increase, the effect which vigorous growth has in causing trees to be more resistant to or better to recover from insect attacks are all subjects now being investigated. Wider problems, too, such as the value of mixed woods as compared with that of pure woods in reducing risk of insect outbreaks, and the value of natural regeneration as opposed to the artificial regeneration of woodlands, are being studied, and, as we have pointed out, the variation of the extent of parasitism and its relationship to the density and composition of the forest is also attracting attention.

In agricultural entomology ecological studies are being made of the insect fauna of the soil, and we may soon expect a study of hedgerow insects, but the

study of parasite control will, in agricultural entomology, probably begin in fruit farming and with a study of the parasite complex of some such insects as the Winter and Codling moths or in pastoral farming with a study of such an insect as the Grass moth (*Charæas graminis*). In this work the foundations of a fuller understanding of the value of parasites as controlling factors will be obtained and the term "parasite control" will no longer be restricted in practice to the somewhat special use of parasites against exotic insects only.

The fact is that an understanding of the ecology of an insect pest is really necessary in applying all types of control methods. For generations the use of bait traps consisting of pine logs or pine bark has been practiced against one of the most important insect enemies of re-afforestation, but it is only within recent years that their use has been completely justified as a result of long-range ecological work.

The Large Pine Weevil (*Hylobius abietis*) is known to the forester as the worst enemy of his young pine plantations, established to replace the crop just felled. In the older pine woods the weevil, a small beetle with a longish snout, is quite innocuous. It feeds in the tops and branches of the trees, causing no appreciable harm, and breeds in the roots of dead or dying trees or in branches broken off by snowstorms or wind, and in the stumps and roots left by the forester when thinning his woods.

Forests are always planted densely in order to cause the trees to grow up to the light with few branches, and consequently as the more vigorous trees crowd out and suppress the less vigorous these poorer trees are removed as "thinnings." Now it can be shown that after a thinning has taken place the numbers of the weevils in a wood or forest plot increase in numbers because of the increased breeding ground afforded by the stumps of the thinned-

out trees. So, too, when the forest becomes mature and is "clear felled" all the trees are removed and their stumps afford abundant breeding ground for the weevil. Meanwhile the forester replants the area and thus provides the weevil with a supply of tender trees eminently suitable as food. The weevil is then in an ideal position with food for its grubs in every stump and for itself in every young tree or "plant." As it increases in numbers it soon devours the bark and buds of the young trees and in many instances felled pine areas in this country have been re-planted as many as three and four times because of the depredations of *Hylobius*.

The measures taken by the forester to control the weevil are various and are also of varying value. Until recently all of them were devised on the assumption that the place and time to control the weevil were after felling in the felled area itself. Many of the measures practised were of very little value, as, for instance, the painting of the stumps above ground with creosote to prevent the weevils from laying their eggs in them. That measure was useless because the weevil always lays its eggs in portions of the stumps below soil level. Another worthless measure was the spraying of the young plants with poisons such as lead arsenate. That measure is useless because the weevils do not eat the outer bark of the twigs or stems of the young trees, but reject that bark and gnaw through and under it to the tender green cambium below, which is not reached by the arsenic spray. Professor Escherich suggests that the weevil is immune to poisoning by arsenic, but there is reason to doubt his suggestion.

A more useful measure against the large pine weevil is the use of heaps of fresh pine sawdust or of freshly peeled pine bark or freshly cut pieces of pine branches to attract the weevil, which come in numbers to these bait traps and are then collected

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and destroyed. This method is a time-honoured one, and is, despite its simplicity, the best and cheapest method of control. The only defect in its use was that it was applied at the wrong time. The large pine weevil is always present in our pine woods, usually in small numbers, and it is only when its breeding ground is increased by felling operations that it ever attains sufficient numbers to become injurious.

If the forester traps it before he begins felling, as he can easily do, then he can reduce its small numbers still further, and, indeed, to such small numbers that even when felling does take place some years must elapse before the few weevils left after trapping can rear sufficient offspring to cause any serious injury. This method of early trapping in the woods before they are felled has been recently tested by experiment with highly satisfactory results. It has the advantage that it actually prevents weevil outbreaks at much less cost than the older system of trapping after felling, which was, too, merely a palliative measure. The period during which the stumps on a felled area remain attractive and suitable to the weevil varies with the locality, but in the dry, warm climate of the south it lasts only three years, and in the wetter, colder climate of the North it lasts about four years. By early trapping of the weevil the forester can so reduce its numbers that the stumps cease to be attractive to the weevil before it has had time to increase sufficiently to become a menace to replanting.

This method of control has been based on a detailed study of the weevil and its relationship to forest practice, but some ten years were occupied in completing the work. All the commonly practised control methods were tested experimentally, the parasites of the weevil were studied, parasite control was tried, but after piecing together all the information obtained from these experiments and from observa-

tions carried out in different localities at intervals during ten years, it became evident that the only sound control method was that of trapping in the woods to be felled, a year or two before the felling was to take place.

This work on the control of the pine weevil was carried out by H.M. Forestry Commission. The experimental work was done in two of their forest "Divisions," but its results are applicable throughout the country, and even to another species of *Hylobius, Hylobius pales,* occurring in the eastern United States, and although the work was slow the value of it is not to be measured by its cost. In this particular case the cause of the outbreak is increased food supply, and the best control measure applicable is to trap the insect before the increase of food supply is brought about and so prevent the weevil from gaining advantage of it. It should be pointed out that the method is dependent for success on the co-operation of the forester, and that it is applicable only where forestry practice is well organised and properly planned.

The principle of preventing insect outbreaks by anticipating the operations of the forester or farmer or merchant is still too little employed in entomology to-day. It is, however, a principle which will become more and more applied, and it is especially applicable to the control of insects whose increase is governed mainly by the food-supply factor. Its application depends, however, on the fullest knowledge of the insect's ecology, and in particular on a knowledge of the relationship of the insect to the methods and practices employed in the industry affected. In the investigation of the insects injurious to stored products, such as cacao, spices, and dried fruits, which is being undertaken by the Entomology Department of the Imperial College of Science and Technology, the progress so far made indicates that in the control

of insects in stores and warehouses a wide knowledge of the ecology of these insects will form the only sound basis. In the cacao industry, for example, it is evident that no real improvement in the condition of imported cacao can be looked for until a full ecological study of the Cacao moth (*Ephestia elutella*) has been made, both in the cacao growing countries —such as West Africa—and in our ports at home. Undoubtedly the insect infestation arises because of the accumulation of quantities of cacao, but just when infestation begins, whether after fermentation of the cacao or before that operation, is uncertain. The effect of the presence of mould in the cacao appears also to have some bearing on the extent to which cacao is attacked by the *Ephestia,* and in the case of nearly all stored products there is evidently a correlation between the condition of the products and the degree of insect infestation.

One of the results of the investigation of stored products insects—including insects infesting timber—is to show how very meagre is our knowledge of the real food of insects. As Mr. Uvarov has pointed out in his summary on Insect Metabolism, recently published in the *Transactions of the Entomological Society,* we know very little concerning the chemical composition of the food of insects, and less still of the physiology of their digestion of it. The organised control of insects injurious to stored products will depend on the acquisition of a fuller knowledge of their feeding habits. Meanwhile it may be repeated that many of our stored products pests are scavenging insects, which under natural conditions feed on moulds and the products of decay, and that the first step towards their control is to insure freshness and cleanliness in our stores. Better hygiene combined with the judicious and timely use of chemical and physical control measures are at present the best methods of reducing outbreaks of insects in our

stores of food and the raw materials of industry. The two measures must go together, however, for chemical or physical control measures of themselves are merely palliatives, and our hygienic measures are still limited in their effects pending a fuller knowledge of the insects' ecology.

In the control of stored products insects, success will depend very largely on the co-operation of the producers in our Colonies and of the importers and merchants at home, and one of the most interesting parts of the writer's work in directing the stored products research at the Imperial College is that which is concerned with trying to form a liaison between the Colonial producers and Government officials and the wharfingers, merchants, and manufacturers at home. It is also extremely interesting to find that in England we can carry out research on such insects as the Cacao moth, the Nutmeg weevil (*Arœcerus fasciculatus*) and the dried fruit moth (*Plodia interpunctella*) which is both interesting and helpful to our colleagues in West Africa, Trinidad, and Australia. For example, one of the needs of the Gold Coast authorities in their work on the improvement of cacao marketing was a knowledge of the insect conditions prevailing in their cacao on its arrival at our home ports. This we have been able to supply, and in return have been able to secure an exchange of programmes of investigation so that part of our investigations at home run on parallel lines with the work on the Gold Coast. The result is that a full knowledge of the ecology of the insect pests of cacao may soon be hoped for, and that when control measures come to be devised they will have for their basis a real understanding of the problem as it appears in the cacao growing country and at home, and an understanding of the difficulties of all the parties concerned in the cacao trade. This very desirable consummation of the work, when it is achieved, will

have been possible because of the ecological work done. It is no exaggeration to say that in all economic entomology problems the best hope of a solution lies, not in the indiscriminate and hasty resort to the use of insecticides, but in the frank and open investigation of all the aspects of the problem with the object of placing any control measures devised on a broad and sound basis.

The use of insecticides and of heat and cold in the control of insects has an important place of its own in economic entomology, but the basis of all control measures ought to be a thorough study of the biology and ecology of the insect concerned. Even in the use of insecticides and of physical control measures much can be gained from a knowledge of the biology of the insect, and we may now consider these chemical and physical methods in some detail.

CHAPTER V

THE CONTROL OF INSECTS BY CHEMICAL AND PHYSICAL MEANS

The use of poisonous chemicals and of high and low temperatures for the destruction of noxious insects is a very old practice and is still the most popular and most generally employed destructive measure. In its application there is, however, one serious limitation—namely, that the chemical or physical means used should kill the insect without having any deleterious effect on its food or surroundings. Obviously, one would not try to destroy insects on one's potato patch with a chemical which would also destroy the potatoes. This limitation of the chemical substances

or physical means to be used is an extremely important one which affects the whole question of control by chemical and physical measures. In the first place, because one cannot readily submit plant feeding insects to fatally high or low temperatures—lethal temperatures as they are termed—without at the same time submitting the plants to these temperatures, the use of this control method is practically ruled out against pests of agricultural crops. Accordingly, in agricultural entomology, chemical means only are used at present, and in general they are spoken of as insecticides.

The use of any chemical or chemicals as an insecticide is limited in agriculture by its effect on the crop and in industry by its effect on the product. For this reason and because substances useful as insecticides in agriculture—*e.g.*, coal tar products as winter washes are not applicable in industry and *vice versa,* it is advisable to consider these two branches of entomology separately. In actual practice the study of insecticides for use on growing crops is quite a distinct branch of entomological chemistry from the study of insecticides for use on stored products.

The agricultural entomologist recognises two classes of insecticides, which he terms stomach poisons and contact poisons. The first class are the insecticides which are believed to act when they have been eaten by the insect and have entered its stomach. The second class are the insecticides which are presumed to act merely by touching or making contact with the insect's integument—or "skin"—or by entering its respiratory system through the little openings or spiracles which open on the sides of its body. Whether this classification is really scientific is doubtful, but it is useful inasmuch that stomach poisons can be used only against insects which gnaw solid food and are of no value against insects which suck the sap or juices of plants by piercing them. Thus we may

say that in general stomach poisons are used against the "biting insects"—such as locusts, caterpillars, leaf-eating beetles, and weevils—and contact poisons are used against the "sucking insects"—such as greenfly, plant bugs, and scale insects. Contact insecticides do, of course, act on biting insects and are used against them, but their particular use is for the destruction of the sucking insects.

Stomach insecticides are usually applied in two forms: as liquids containing poisonous salts—such as arsenical compounds in suspension—and as dusts consisting of poisonous salts in admixture with some dry substance—such as chalk or kieselguhr—which helps in the "spreading" and adhesion of the dust and reduces the danger of wetting.

The chemical substances suitable as stomach insecticides are rather limited in number, and, in fact, arsenical compounds are in practice the most generally useful. They have the desirable attributes that they are not water-soluble and are, therefore, not washed off the plants by rain, that they are relatively cheap, and that they are easily procured. They are, too, relatively highly toxic. Within recent years arsenical dusts have been preferred to liquid arsenicals, and with the development of aeroplane dusting it seems likely that they will gradually replace liquid arsenicals. Arsenic compounds are also used in the making of poison baits which are employed against such insects as locusts and cutworms and consist of bran and poison moistened with water, with or without the addition of treacle or molasses or of bundles of herbage dipped in strong arsenic "solution."

The purpose of the stomach insecticide is to cover the plants to be protected with a fine coating of arsenic so that in feeding the insect absorbs or swallows the arsenic with its food. To insure a general distribution of the arsenic over the plant the insecticide is applied as a very fine spray or mist. The

objections to arsenical compounds as insecticides are that their careless use may result in "scorching" of the plants sprayed—this happens when water-soluble arsenic is present in the spray used—that they are highly poisonous to man and other animals, and that they are rapidly increasing in price.

Apart from arsenical salts the chief inorganic salts used as stomach poisons are copper sulphate—the basis of Bordeaux mixture—and the fluorides and fluosilicates of sodium.

The contact insecticides offer a much wider range of substances than the stomach poisons, and within recent years the investigation of possible substances for use as contact insecticides has almost revolutionised the use of insecticides, so that to-day the entomologist who would keep abreast of new knowledge must be prepared to undertake the serious study of organic chemistry. The most important contributions to our knowledge of contact insecticides have been made by the Insecticides Department of the Rothamsted Agricultural Experiment Station, at Harpenden, under the leadership of Dr. Tattersfield. The results of his work are of too technical a nature to be described here, but one very important general result of it has been to raise the standard of all insecticide work and the standard of tests of the efficiency of insecticides.

In general, the progress recently made in the investigation of contact insecticides has been to direct attention to organic compounds, particularly derivatives of shale and coal-tar oils, and to the toxic extracts of such plants as *Tephrosia, Deguelia,* and *Chrysanthemum.* It seems, in fact, that pyrethrum extracts derived from species of *Chrysanthemum* may yet prove the most toxic of insect poisons, and that their use may be greatly extended. Pyrethrum powder, derived from the dried and powdered flowers of *Chrysanthemum,* has long been used as an insect powder, but until recently the true chemical nature of

the toxic principle it contained was not certainly known.*

In Germany and in Holland an investigation of the so-called tar distillates—oils distilled from coal-tar—has led to a very important extension of the use of the substances in the control of fruit insects by applying them as winter washes when the trees are dormant.

In general, shale and coal-tar oils, plant poisons like pyrethrum, and sulphur compounds, afford the most promising sources of contact insecticides, and with the extension of these sources there has also developed a much more accurate chemical knowledge of how insecticides act and why they act. This will doubtless soon be followed by a better knowledge of the physiology of insecticides, and the control of insects by insecticides will be placed on a rational, scientific basis. Such a development is highly to be desired in order to check the shameless exploitation of the anxious crop grower by firms whose sole interest in selling their "insecticides" is to derive revenue from some by-product of their manufacture, the value of which as an insecticide has often never even been tested and is assumed to exist only because the by-product is evil smelling or contains some form of cresol. It is no test of an insecticide to immerse insects in it. The real test of an insecticide is its capacity to reach, penetrate, and to kill the insect in its normal habitat, and this is no easy matter.

One point to be noted with regard to the use of insecticides in agriculture is that as a rule their effect is immediate, and there is no great demand for an insecticide which shall be lasting in its effects.

In industrial entomology the control of insects by insecticides and by their submission to extremes of

* Some of the most efficient "fly-killers" consist of a combination of a heavy paraffin and pyrethrum extract.

heat and cold are almost the only measures available against them at present, but even so the use of these measures is still largely haphazard and unscientific. In the choice of insecticides, among which poisonous gases are the most generally used, the same limitations occur as in the application of insecticides to plants. Any substance used must not be deleterious to the product treated, and in fumigation by hydrocyanic acid gas, for example, the greatest care is necessary to insure that no harmful effect results. This gas is absorbed and retained by different products in different degrees. Thus, while cacao beans will absorb only thirteen parts of the acid per million by weight, the same beans if crushed to powder will absorb as much as sixty-three parts per million. Some products rich in essential oils—such as cloves and other spices—cannot be fumigated because they absorb so much of the gas.

Hydrocyanic acid, because of its rapidly toxic effect on insects and of its easy preparation and application and relatively high penetrating power, is one of the most useful insecticides for use in commerce, but at present its use is seriously limited because of the very variable absorption of the gas by different products. Not only is the gas absorbed, but it is held or retained, and such products as dried fruits may retain appreciable quantities of hydrocyanic acid for many weeks after fumigation has been done.

Another very useful fumigant, carbon bisulphide, is limited in use because it is highly inflammable, and many otherwise useful sprays consisting of heavy paraffin oils and pyrethrum extract are limited in use for the same reason.

The use of extremes of heat and cold in stored products entomology is not so frequent or so general as the use of insecticides. In the United States, as Professor Chapman informed the writer, some flour millers raise the temperatures of their mills and ware-

houses during the week-end to eliminate such insects as the meal moth (*Ephestia kuhniella*) and the grain weevils *Calandra* and *Sitophilus*. In the timber industry the sterilisation of oak and ash timbers infested by *Lyctus* beetles and by long-horned beetles, especially the so-called "red-headed ash borer" (*Neoclytus erythrocephalus*) is becoming a general practice in the United States, and is now practised by the more enterprising timber importers and merchants in Britain. The method was devised by Messrs. Craighead and Snyder, two leading American forest entomologists, and in its present form is practised in conjunction with the kiln method of seasoning timber. The exposure of insect-infested timber in a steam kiln to a temperature of 130° Fahrenheit at a humidity of 100 per cent. for three or four hours is sufficient to sterilise it. Experimental work to improve this method, and, if possible, to reduce the degree of temperature which is higher than is desirable for seasoning purposes, is in progress at the Forest Products Research Laboratory of the Scientific and Industrial Research Department at Princes Risborough.

The use of very low temperatures to check insect infestation of stored products is not yet in general use. At the Imperial College experimental work on the freezing of insects infesting almonds and nuts is in progress, and it seems that the method has distinct possibilities commercially. The method tried was double freezing—that is, the freezing of the insects for some hours, then submitting them to a warm temperature for a short period, and finally freezing them again.

The defect of all these methods of control against insects in stored products is that, while they get rid of the insects for a time, they do not prevent re-infestation. This is a defect which also exists in the application of insecticides in agriculture, but because the crop is only a short time on the ground, except in

fruit farming, the temporary nature of the effects of insecticides is less of a drawback than in commercial entomology.

Obviously, insecticides and sterilisation by heat and cold must be supplemented by other measures, and in commercial, as in agricultural and forest entomology, we are once more forced to face the study of commercial entomology on a fundamental basis. In this more scientific investigation there are two main lines of work to be followed. The first is to study closely all the conditions or factors which contribute to the increase and continued occurrence of insect infestation. The second line of study is to investigate further the use and application of insecticides and physical destructive agents from a bio-chemical and bio-physical standpoint.

In the first line of study the co-operation and goodwill of all the parties engaged in the particular branch of trade or commerce is essential. One of the most difficult and least pleasant duties which the commercial entomologist is called on to perform is to decide in some dispute regarding damage resulting from insect infestation which party is responsible, and in nearly every instance it is evident that all parties are to some extent responsible, because all of them have contributed to the favouring of infestation. One case which occurred some years ago in the timber trade will serve to illustrate this and serve to indicate the nature of commercial entomological problems in general. The case began with a request for advice regarding the identity of some grubs which were destroying the fittings and furnishings of a small liner. The grubs were identified as those of one of the powder post beetles (*Lyctus brunneus*) and, in response to further inquiry, it was reported that the presence of the insect was due to the use of American oak, for the fittings and furnishings, which contained a high percentage of sap-wood. On the strength of this in-

formation the owners charged the shipbuilders with responsibility for the destruction. Then came a request from the shipbuilders for advice, which resulted in their approaching the timber merchant and importer. He, too, came for advice, and it may be noted that all three parties were acting quite independently in this regard, and that none of them knew the source of the other's information. Finally, it became impossible for the writer to conceal from the three parties that each was consulting him, and they were advised to settle the matter among themselves, and each to bear part of the loss. The reasons for this were that while the timber importer had infested stocks of American oak in his yard, so too had the shipbuilder stocks which had not been obtained from this particular importer. The shipowners also had certain furnishings, not supplied by the shipbuilder concerned, which harboured the *Lyctus* and, with the infestation so far advanced, it was literally impossible to allocate original responsibility. The parties were advised of this position, and, realising that at law the case would be decided on other than strictly scientific grounds, they settled it out of court.

One of the difficulties which retard the prevention and control of insect infestation in commercial products is the very natural desire of the parties suffering to place the responsibility on somebody else. This, coupled with the desire and need for secrecy resulting from competition in business, makes the acquisition of accurate information regarding the real origin and extent of infestation very difficult and usually impossible until all the parties find themselves sufficiently hard hit to make it worth their while to face their difficulties frankly and in conjunction with one another. So great sometimes is the desire to conceal the occurrence of insect infestation that on one occasion recently one party destroyed part of a consignment of goods rather than risk marketing it and

so letting its rivals in the trade know that their goods were sometimes infested.

As we pointed out, however, in referring to the losses caused by insects, this hesitation on the part of commercial firms to face the facts of insect infestation of their wares is gradually disappearing, and instead of trying to saddle their colleagues in trade with responsibility all parties are beginning to realise that only by a combined effort can their problems be solved. In Germany there has been recently formed a laboratory for the study of stored products infestation, which is supported and financed by commercial interests. In England research in stored products entomology is still dependent on Government support, but there are reasons to hope that soon commerce itself will contribute towards the work.

On the bio-chemical and bio-physical side the work on the prevention or reduction of insect infestation is concerned mainly with the improvement of the insecticides now in use—for example, in the application of hydrocyanic acid gas, and in the investigation of the action of insecticides and temperature both on the insects and on the products. The Ministry of Health has, naturally, an interest in this work, but it is to be wished that their attitude towards the sterilisation of foodstuffs by insecticides was less negative and more positive. For example, a definite pronouncement by the Ministry of Health as to what degree of absorption of hydrocyanic acid (prussic acid) by food products is safe would greatly help both the entomologist and commercial interests, and a more active policy in the direction of a sterner restriction of the marketing of infested foodstuffs would also benefit both the trade and the public. This raises the question of legislation as a means of insect control.

CHAPTER VI

LEGISLATION AS A CONTROL MEASURE AGAINST INSECTS

It may seem absurd to consider the suppression of insects by law. One does not hope to prevent the ubiquitous house-fly from disturbing a post-prandial "forty winks" by threatening the law against it. Nevertheless, legislation directed against the spread of injurious insects exists and is one of the most difficult and least grateful branches of economic entomology.

In general, legislation is directed mainly against the introduction into a country or state of injurious insects from other countries or states or against the spread or dispersal of some injurious insect within a country. As a rule the insects "scheduled" are pests of important staple crops, and legislation is concerned mainly with insects attacking plants and with the prevention of the ingress of injurious insects on imported plants or plant products. Sometimes the measures are directed against a particular insect, as when our Ministry of Agriculture restricts the importation of potatoes from certain countries or districts of a country to prevent the entry of the Colorado beetle, or the importation of cherries to prevent the entry of the cherry-fly. These special measures are, however, emergency measures and as a rule legislation aims at the more general policy of preventing the entry of injurious insects on their host plants. In the United States more drastic measures are taken than in any other country, and the legislation embodied in what is known as "Quarantine 37" amounts almost to the total prohibition of plant imports. As a result, in Europe, and particularly by Holland, this plant quarantine

Act is regarded as an abuse of entomological legislation by political and commercial interests.

The prime defect of all legislative measures is that they may be abused, and while drastic legislative measures to prevent the introduction of a serious pest into a country may at times be necessary, such measures should be regarded as emergency measures and removed as soon as the danger is over.

In England legislation against the introduction of injurious pests is enacted through the Diseases and Insect Pests Acts, which are administered by the Ministry of Agriculture and Fisheries and, in so far as pests of forest trees are concerned, by the Forestry Commission in consultation with the Ministry. At present it consists in the restriction of the importation into England of all nursery stock (or young plants) from countries other than Scotland, Ireland, and the Channel Islands, which is not accompanied by a certificate that such stock is free from certain insects, such as the Cherry and Apple Fruit flies, the Potato moth, Capsid bugs of apple and the Colorado beetle. The list of pests named in the Diseases and Insect Pests Acts are known as "scheduled pests," and any nurseryman or private individual finding a scheduled pest on his premises is required to notify the fact to the nearest police station, which then informs the Ministry of Agriculture. On receiving such a notification, the Ministry has powers to visit and inspect the premises and to restrict the removal of the infested plants or of any plants from the premises or to order their destruction. In addition the Ministry has a staff of inspectors at our ports, whose duty it is to inspect consignments of imported plants for insect pests and fungus diseases.

This system of legislation works fairly smoothly, is apparently effective, and is relatively easily modified to suit special emergencies. Thus the Ministry can at any time cancel an existing D.I.P. Order, as it is

called, and modify it or issue a new one. The system is not unduly irritating to our foreign customers and puts them on their honour, rather than antagonises them, by accepting the certificates of their own plant protection services as a guarantee of clean stock. It is, in fact, based on the only rational basis of insect legislation—the reliance on the entomologists and mycologists who compose the plant protection services of the country concerned. The ways in which an insect may enter a country are so numerous and so varied that it is really impossible to insure absolute protection against its introduction. Even the drastic quarantine system of the United States cannot insure complete elimination of the risk of injurious insect introduction, and, that being so, the less irritation and the less antagonism set up by legislation, the better. Moreover, when, as we must frankly admit, the complete prevention of the entry of injurious insects is impossible, it is evident that the best safeguard against their spreading and causing devastation is to have an efficient staff of entomologists always on the lookout for them. The more efficient and the better equipped that staff is, the greater the protection.

In this country we take at present no steps to prevent the introduction of injurious insects in imported products other than plants. We have suffered recently from an invasion of powder post beetles in imported timber from the United States, and the question of legislation to check that invasion has been raised in commercial circles. Unfortunately any legislation now will not much remedy matters, because these beetles are established in almost every yard and workshop in the country which uses oak and ash timber. Moreover, the remedy lies rather in the hands of the timber trade, which can protest, and is, in fact, protesting, to the American trade and can back up its protests by cutting down prices. The Forest Products Research Laboratory at Princes Risborough is, however, collect-

ing data and statistics regarding the extent to which American timber arrives at our ports infested by *Lyctus* beetles, and there is no doubt that when these figures are available a satisfactory reply from the United States timber trade will be forthcoming without recourse to legislation.

Legislation is a necessary evil; alone it is ineffective in excluding injurious insects, but combined with an efficient entomological service it can serve a useful purpose. In fact, with legislation, as with all methods of insect control, efficiency depends far more on the entomologist and on his knowledge and tact than on any form of words or composition of an insecticide.

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THE STUDY OF BIRDS

AN INTRODUCTION TO ORNITHOLOGY

By E. M. NICHOLSON

Author of *Birds in England*; *How Birds Live*, etc.

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THE STUDY OF BIRDS

CHAPTER I

INTRODUCTORY

A BIRD is known by its feathers, not only proverbially, but in scientific definition. Certainly it has other obvious characters—of flight, of going on two feet, and of laying eggs instead of bringing forth the young alive—but considered as points of distinction these are of less essential importance, since there are mammals which do each of these things, and, on the other hand, birds which cannot fly. In the scale of life it comes next after the mammal, but its relationship to the reptile is much more marked. In fact, both these undoubtedly spring from a common stock, and the most primitive of fossil birds might almost be mistaken for a reptile. A bird has the hottest blood (up to 112° Fahrenheit) and therefore the swiftest nervous reactions of any vertebrate. Its brain is not remarkable, but it possesses a set of fine instincts sufficient for the demands which life commonly makes on it, and it combines extreme vitality with most enviable powers of endurance. At its best it is the most free of all animals except man, enjoying long life and perfect health, the power of freely changing its environment, and faculties which are a source of constant pleasure, like flight or elaborate song. Yet it is

essentially a slave, being incapable of reflection except in the most primitive sense and entirely at the mercy of a series of delicate yet not especially subtle trains of behaviour, to which the circumstances of the outer world are perpetually acting as a stimulus or "trigger." A human being who possessed the mentality of a bird would be considered irresponsible, unintelligent, but gifted with inexhaustible intuitions, quite lacking in character but ready and alert, unimaginative, and entirely without any morals.

In size a bird may range from a creature no bigger than a beetle to something considerably taller than a man; its tail may be practically absent or prolonged to a far greater length than the body it belongs to; its wings may be developed to the extent that it is hardly able to alight with comfort, or so atrophied that it cannot fly; it is by nature prone to the most fantastic extravagances of colour, of ornament, of voice, of behaviour, or of specialised adaptation.

It is clear, then, that the study of birds, which we call ornithology, is curiously full of pitfalls. There is so much temptation to be diverted into the mere cataloguing of plumages, the chronicling of wanderers far outside their range, into idle theorising about migration, collecting pretty pictures or beautiful eggs, or regarding with a gush of sentiment these beings so conspicuously free from the evils to which ourselves are conspicuously exposed. Yet these activities, although birds are their subject or their victim, have little else in common with ornithology proper. Some of them had once a real value which they have obstinately outlived; others never had any value except of a negative sort, nor ever will. Orni-

thology, as it is to be considered in these pages, must be taken as the dispassionate concerted effort of a few men (separated by wide tracts of time and space) to attain, through constructive observation, to a more profound understanding of birds. We will, therefore, best fulfil our purpose, not by reviewing the various orders and families of birds, their distinguishing marks, their peculiar habits, and the number or kind of eggs they lay, but by outlining the principal methods by which ornithology is at present proceeding, and the problems which it is solving, or hopes to solve in the future.

CHAPTER II

HISTORY OF ORNITHOLOGY

Although the ancient Egyptians were expert enough to leave us a remarkable likeness of the red-breasted goose, and there are some well-known references to birds in the Old Testament, the science of ornithology must be taken to begin with Aristotle. He encountered the subject in the course of his monumental survey of human knowledge, and was never able to devote himself to it with much detail, but, like everything else he touched, ornithology was permanently enriched by his fruitful and penetrating mind. As the dominant influence in medieval learning he ought to have been able to stimulate some of the intellectuals between the thirteenth and fifteenth centuries into paying some attention to the study of birds, but the Middle Ages were too biassed in the other direction to be attracted by any sort of science. It was only when they gave way to the Renaissance, and when their teacher himself shared the fate of Don Quixote, that disciples of Aristotle began to appear to carry on this particular branch of his researches. It was doubly unfortunate for his reputation as a naturalist that after such long neglect he should have been resurrected chiefly in order to pour scorn upon the fables which he occasionally allowed to deceive him. A philosopher, with almost a blank sheet to start with, was not likely to be unimpeachably

accurate on questions of fact, but there has never been an ornithologist who had such ample excuse for his errors, and the congenial task of pointing out that cuckoos do not turn into hawks every winter, nor geese hatch out of barnacles, may easily lead us to overlook how fundamentally his observations are true. His data were few and faulty, but he had a fine and discerning mind reinforced by a wide knowledge of men and things, which enabled him better than almost any of his successors to realise the true function of natural history among the sciences. He clearly understood that anything like the pursuit of birds for birds' sake, whether as a collector of skins or eggs, pictures or memories and impressions, could never be the worthy object of a science, which, if it is to fulfil itself, must work by the means at its disposal towards a solution of the scheme of things. Ornithology, that is to say, must not be content merely to set before itself a complete understanding of birds; it must aim at the understanding of life itself so far as birds can throw any light upon it. Acting on this conviction, Aristotle not only brought to bear on natural history his great extraneous learning, but used his knowledge of Nature, on the other hand, to illuminate his view of human institutions. One particular passage from the *Politics* is worth quoting here, since it forms incidentally a much better general statement of the territory theory, so important in modern ornithology, than anything which I could find elsewhere, or hope to compose myself:

"Again there are many sorts of food; and therefore there are many kinds of lives both of animals and men: they must all have food, and the differences in

their food have made the differences in their ways of life. For of beasts some are gregarious, others are solitary; they live in the way which is best adapted to sustain them, accordingly as they are carnivorous or herbivorous or omnivorous; and their habits are determined for them by nature in such a manner that they may obtain with greater facility the food of their choice."

Only during the present century have zoologists begun properly to grasp that economic basis of social organisation and distribution among animals which is asserted here in words written over two thousand years ago.

When modern ornithology awakened, as it first did with the works of men like Gesner, Dean Turner of Wells, Belon, and Dr. Caius in the sixteenth century, it took on a strong and almost fatal bias towards rarities and freaks. The generations whose poets were attracted towards ". . . the Anthropophagi, and men whose heads do grow beneath their shoulders" produced as a matter of course scientists obsessed with insignificant and rather disgusting abnormalities, like kittens with two heads, monstrous births of all kinds, enormous gall-stones, or horns of supposed human growth. The whole tendency was to despise and practically disregard whatever was common and to exalt the extraordinary or the rare, specimens of which began to be hoarded in dusty and verminous museums, where there was little labelling and no arrangement at all. This futile tradition, although long ago discredited, continues to stifle the progress of ornithology to this day. It shows itself especially in the abysmal condition of most of the

collections of "stuffed birds," at any rate in Europe, and in the unreasoning worship of rarity common to those who collect and those who simply observe. The cult of varieties and freaks is slowly losing ground, although they are still considered better worth recording than facts for the want of which ornithology is at many points held up. We can only understand the present position when we consider that, in England at least, it would be more feasible to take a census of pied blackbirds or of white sparrows than of any common species, the statistics of which would have a certain scientific value.

We may say without serious injustice that the sixteenth and seventeenth centuries, with a great part of the eighteenth, were consumed, so far as ornithology was concerned, in the enumeration of species and the compilation of facts about their plumage, reproduction, and their more striking habits. It was mostly hack work, involving little genuine research and wholesale borrowings from earlier writers, and there is no reason to be surprised that no first-rate figure appears in it. In so brief a sketch as this it is only necessary to name the Englishmen, Francis Willughby (1635-1672) and John Ray (1627-1705), who laid the foundations of scientific classification, and Linnæus the Swede (1707-1778) who reduced all the species of plants and animals—birds, of course, included—to an orderly system of Nature, in which he allotted every known species to its genus, every genus to its order, and every order to its class. Except for the separation of sub-species, of which any species may possess a large number or only one, and the discrimination of the family, his work is still the basis

of classification, upon which subject more must be said later.

During the lifetime of Linnæus natural history became popular. Before the *Lyrical Ballads* had lent Nature a romantic prestige, even during the most formal and classical epoch, when Versailles set the tone of European civilisation, a tendency towards nature-worship began to appear. Under such influences as Thomson's *Seasons* in England and Buffon's glowing prose in France to know something about Nature became definitely a fashionable accomplishment. Although the Nature thus embraced with as much enthusiasm as the eighteenth century would permit itself to show was not quite Nature as we know her, but something much more orderly, in harmony with reason and a broad-minded theology, yet this popular interest was bound to have most tremendous effects. It meant that natural history could no longer be the special preserve of a rather dull and pedantic set of men, but must accustom itself at least to being interpreted in terms of ordinary lay experience. The condition was for the first time imposed that natural history must be made interesting, and it is significant to find Buffon, the most typical naturalist of the period, asserting most positively that only those books would live which were the best written. Now, when it becomes a question of popular appeal, birds have an easy superiority over any other branch of natural history; it therefore happened that ornithology, which had hitherto had to depend largely on an occasional fillip from some versatile botanist or doctor, suddenly passed into the hands of a large corps of enthusiasts, some of whom

cared for very little else. Botany and entomology, which had both had a better start, lost something of their lead; mammals got rather lost between the game-hunter and the museum zoologist, fishes and reptiles suffered from a neglect which to some extent still persists. Birds, a comparatively small and limited class, rose rapidly to a popularity which they have never had to yield.

The period while this change was taking place is spanned by the lives of two men whose work had a lasting influence upon ornithology. Gilbert White (1720-1793), beginning from a quite conventional passion for gardening, turned, under the influence of some of the leading naturalists of his day, to a general observation of Nature, and especially of birds. He was not particularly interested in the systematic work or the oddities which had absorbed his predecessors, and he set himself to find out something about the ordinary life of the ordinary animals of his parish. Half-unconsciously he became the leading figure in a revolution of method and outlook, for no one who read his observations, taken directly from Nature with a pentration and sense of proportion which had never before been concentrated on the subject so long, could continue to tolerate the arid repetitions of the standard natural history at that time. His *Natural History of Selborne,* limited as it was to a single parish, was at once translated into German, and has run through endless editions in Great Britain and America from its publication in 1789 until the present day. It is the outstanding classic of natural history, to be read with increasing pleasure over and over again, and its influence on succeeding ornithologists has been tre-

mendous. One of its first and most enthusiastic readers was Colonel George Montagu, who applied White's principles with conspicuous success in his *Ornithological Dictionary*, the basis of all the standard works on British birds which have been written since 1802.

Unfortunately, firearms developed more rapidly than ornithology. Through most of the nineteenth century slaughter of specimens and accumulation of egg-shells proceeded on a colossal scale. Of course a certain number of specimens were needed in order to distinguish the various species and to elucidate their changes of plumage and their relationship to one another. But this wholesale killing and looting was not only far in excess of scientific requirements at the time, but had rarely the justification of being done in any scientific spirit or on scientific lines. Every specimen which is to be of any serious value, ought to have attached to it the minimum of data as to where it was procured, on what date and by whom, with the colour of the soft parts recorded at the moment, and the sex as determined by dissection. In few cases was this duty adequately performed, and in many there was no attempt to perform it. Masses of specimens were wasted in every part of the world, and many which were brought home to English museums from abroad lay stored without any arrangement, and identification, or any efficient preservative, until they finally had to be thrown away. There are even now few British museums, large or small, which do not conceal relics of this senseless and unscientific slaughter, seen by their custodians only at an occasional spring-cleaning and by the public

never. The stuffed birds which ornamented the houses of persons of ornithological tastes and a great many hotels are equally an indication of the nineteenth-century spirit. But this period, however wastefully, did succeed in sorting out the birds of the world in a comparatively thorough manner, and towards its end the haphazard collection of material about habits—especially, of course, peculiar ones—grew into a fine and intensive study of life-history. In England the outstanding figure of this school was W. H. Hudson, followed more lately by Edmund Selous (who brought it to an astonishing degree of intensity) and by Professor Julian Huxley, who has restricted himself mainly to courtship and display.

The opportunity for such purely individual observation was, however, nearly lost through the long delay in taking it up, and when it at last showed signs of flourishing most of its potential recruits were absorbed by newer activities. Bird photography, which promised to combine the obtaining of valuable pictures with a rich harvest of observations gained during long periods of intimate contact with breeding birds, absorbed the energies and enthusiasm of a large number. But to these the photography has usually proved of more importance than the bird; they are with few exceptions photographers first and ornithologists afterwards, and in comparison with their opportunities their contributions to the sum of knowledge have been disappointing. Bird-marking and the bird census, which also made their effective appearance about a generation ago, have become such important instruments of research that they must form the subject of special chapters. The territory

theory, foreshadowed as we have seen by Aristotle and later by Gilbert White and others—even Oliver Goldsmith was aware of the territorial holdings of the robin—began in the twentieth century to be properly worked out, and since its essential problems were exposed by H. Eliot Howard in his *British Warblers* (1907-1914) the fundamental importance of the subject has been more nearly realised, and a certain, although quite inadequate, amount of field observation has been done on it. Bird protection, which was brought to the front by the unlimited slaughter during the nineteenth century, and the need for preserving many species from the extinction then rapidly overtaking them, has also to be dealt with elsewhere. By 1900 we have reached the point where ornithology ceases to be a history, and becomes an account of the lines of current work.

CHAPTER III

CLASSIFICATION AND COLLECTING

It needs no expert knowledge to detect that a sparrow is more closely related to a starling than a starling to a swan. The most elementary study of birds is sufficient to bring out the fact that there are many individuals, identical in heredity and often in plumage, interbreeding regularly with one another and with none else, and such a group is recognised as a *Species*, distinguishable from other species by superficial characters of form and habit, sometimes very slight, sometimes extremely conspicuous. Nor do we have to go very far before realising that the species themselves fall into groups, and we divide these groups of species into three degrees of consanguinity; first, the *Genus*, confined to very close relations having all their fundamental characters in common, then the *Family*, which may include many genera, and finally the *Order*, which unites all families conforming to the same general specification. The sequence in which these Orders should be taken, and of the various families within them, is still a matter of dispute, British naturalists usually beginning with the *Passeres* and finishing up with game-birds, while Americans do almost the opposite. But there is general agreement on the principles according to which classification should proceed, and the position of any given species with regard to its relationships is not very difficult to establish.

But the world talks an infinite number of languages, and scientists come from many races; in the absence of any central international clearing-house the difficulty has always been to prevent overlapping and duplication through workers in different countries remaining in ignorance of what has been done abroad. The retention of Latin descriptions, and their publication in recognised specialist journals, has done much to bring the scattered efforts of ornithology into line, but the ideal that any given species should be known universally by a single scientific name, to be used on all labels and references in whatever language they are written, is still by no means realised. Difficulties are bound to arise when the same name is given by two men independently to different birds, or different names to the same bird, and the obvious solution of rigidly adopting the first to be published—the rule of strict priority—is not in practice as efficient as it might be. Partly, it is not always easy to establish, in the case of old and obscure works, which actually appeared first; and partly, it has encouraged the growth of a small school of pedantic and antiquarian ornithologists who spend their time unearthing forgotten sale catalogues and other limbo of the eighteenth and early nineteenth centuries, in order to have the pleasure of upsetting names used unquestioningly by three or four generations of ornithologists.

Probably the most conspicuous example of the inconvenience which may result is that of the common European song-thrush or throstle. For a century and a half this bird was universally known as *Turdus musicus* (Linnæus) until it was shown that the bird intended by Linnæus in his description was actually

the redwing, which had always been called *Turdus iliacus*. In the absence of any spirit of reasonableness, or of any authoritative body whose decisions could be satisfactorily enforced, it was impossible to do anything but bow to the established rule—transfer the name *musicus* to the redwing, in spite of the great confusion involved, and rechristen the song-thrush *T. philomelos*, that being the next senior name. Only a few years later it was claimed that the designation *T. ericetorum*, which had just been unearthed by a too persistent investigation, was prior to *philomelos* and ought to supersede it, but the worm of ornithology turned, as it should have done much earlier, and the pure logic of priority failed to make any impression on common sense reinforced by weariness of the flesh. The majority is by now so tired of the raking up of names which have never been adopted that further enterprise of this sort is likely to be discouraged.

Another fruitful source of dissension has been the question of sub-species, or geographical races. It became apparent, almost as soon as ornithology got down to detail, that there were forms so nearly alike and so prone to interbreeding that they could hardly be called good species, and yet distinguished by sufficiently clear characters (often including a difference of geographical range), to deserve some recognition of their existence. For long the die-hards turned a blind eye upon such creatures, granting specific rank to the most inconveniently obvious races, and until the present century the war between the "lumpers" and the "splitters" was not decided in favour of the latter. It is now conceded that any species may be divisible

into two or more sub-species distinguished by a different range of measurements, or differences of plumage, perhaps only in one sex or at one season, or differences of geographical range, or all three characters, the last being the most important, because the others are more or less conditioned by it. As an instance of the type of nomenclature now in force, the raven belongs to the Class *Aves* (birds), the Order *Passeres* (perching birds), the Family *Corvidæ* (crows), and the Genus *Corvus* (true crows). The full scientific name of the typical European sub-species is *Corvus corax corax* (Linnæus), while the American is *Corvus corax principalis,* being a distinct geographical race. The sand-martin, known in America as the bank-swallow, is in the curious but not unusual position of having for its typical race the same generic, specific, and sub-specific name, *Riparia riparia riparia* (Linnæus).

It is easy when disputes over nomenclature arise, as they so frequently do, for the non-systematic ornithologist to cry a plague on both the houses of the protagonists and to doubt whether the convenience of a universal common standard (existing rather in theory than in actual practice) cannot be too dearly bought. Certainly those who are most obsessed with correct nomenclature and the separation of geographic races are the worst enemies of the causes they uphold; by constantly exaggerating the importance of really trivial points they alienate workers with a better sense of proportion, and if "skin-sorters" is merely one of the more polite of their common designations they have only themselves to thank for it. Yet it needs very little reflection to see that, mechanical and unfruitful as systematy inevitably is, ornithologists

ought to be very grateful to those who have plodded through it. It bears the same relation to the subject as a whole that an index bears to a voluminous book; and if the index-makers have often proved quarrelsome and small-minded, the positive value of their labours is not very much the worse for it. As to that metaphor we must confess that if those responsible for the text had come as near to the completion of their task as those who have been indexing the headings, ornithology would not be in nearly such a backward state as it now is. Since it is necessary that systematy should be worked out, it is equally necessary for collecting to be done, seeing that he who wills the end wills the means. The identification of species, the separation of sub-species, and the elucidation of changes of plumage can only be accomplished when the museum specialists who follow these lines of research have at their disposal a sufficient series of skins, accompanied by authentic data, to form a basis for unexceptionable conclusions.

When we hear an outcry against the collector as an exterminator of rare birds, and find some ornithologists, including the present writer, even arguing in favour of the suppression of private collections, we must not forget that there are valuable branches of ornithology to which collecting is essential. It is not collecting that has proved useless and mischievous, but the average private collector. Relying on the cloak of a scientific mission to protect him, he has during the last hundred and fifty years enjoyed a very happy time pursuing the rarest birds in order to preserve their stuffed corpses in glass cases. He has bribed all sorts of accomplices to persecute them in their few haunts,

defied protection orders, neglected to record the minimum amount of data indispensable for scientific purposes, and followed a secretive individualistic line, contributing little to the common stock of ornithology. The great majority of private collectors have never been scientists following a definite line of research; they have been shooters with an itch for acquiring specimens of rare species, or freakish examples of common ones. Oology, the science of birds' eggs, has proved even more futile. There were always some scientists in the background, to give colour to the exploitation practised in their name by the ordinary private collector of skins, but the subject of eggs, except from an embryological standpoint, has never been scientifically investigated. The result is that after generations of wholesale and senseless accumulation of pricked egg-shells, the simplest facts about these curiously variable and characteristically avian productions remain completely unexplained.

The rules which ought to be followed in the collection of birds and eggs are sufficiently clear. A species more or less rare should never be made the subject of destructive inquiry in connection with any point which might equally well be investigated in a common one. It should be interfered with on no pretext whatever if there is any reason to suppose that the toll may endanger to the slightest degree its existence, even locally. No bird should be shot in circumstances when it is likely to be irretrievable, or too badly damaged for preservation, or where there is no possibility of its being decently skinned. Natives, where any are employed, should never be encouraged to shoot birds indiscriminately; they should be forbidden to continue

to kill birds of which enough specimens have already been secured, or to bring in anything because they think it ornamental. The collector who fosters the belief that there is any intrinsic value in birds or their eggs, and persuades the natives to take up their persecution, whether in Uganda or the Hebrides, has a heavy responsibility. It is the duty of the collector to extract the utmost scientific significance from every specimen he obtains. That is to say, he ought in ordinary circumstances not only to ensure that the specimen is well skinned and clearly labelled, with full data regarding locality, time, and agent responsible for it, colour of soft parts—bill, feet, irides, and orbital ring or wattles if any—at the hour of death, and sex reliably ascertained by dissection; but he should also record the weight, preserve in a distinct and identifiable container the contents of the stomach and crop (unless they can be satisfactorily enumerated on the spot), and look for parasites or any signs of disease. If any serious attempt in this direction had been made by former collectors, one-hundredth of the birds collected would have added ten times as much to our knowledge. As for birds' eggs, except where they happen not to have been reliably recorded, or where the existing series of authentic specimens is too small for an average measurement to be arrived at, it is exceedingly doubtful whether their collection, except by qualified biologists, for one or two highly specified branches of research, has any scientific value at all.

Unlike the individual observer, but like the bird marker and census-taker, the collector does not usually operate on his own. He may have associates in the field, especially on foreign expeditions, and in any

case, if he is working seriously and not merely to gratify a selfish and destructive hobby, he must frequently have recourse to a museum—so frequently, in fact, that it might almost be said that every honest collector is the agent of a museum, either paid or honorary. There are, of course, a great many institutions labelled " museum " scattered over almost every civilised country, and most of these have some sort of a collection of stuffed birds, because stuffed birds are among the exhibits with the most universal popular appeal. But few of these institutions are from an ornithological standpoint to be taken seriously. It is useful to bear in mind, so long as one does not push it too far, that the scientific value of a collection of birds can be approximately gauged by their general state of preservation and by the proportion of skins to stuffed specimens. Broadly speaking, the specimen of scientific importance is a skin; the stuffed bird is not so much a scientific exhibit as an object for popular display. It serves to amuse the public and give some rough idea of what the species looks like in life; the most ambitious galleries also aim at reproducing its natural surroundings, together with the nest and eggs or young, and perhaps the characteristic diet so as to present a memorable picture. But such exhibits are not of much scientific value, and are, in fact, often inaccurate in points of detail; thus the fulmar petrel appears in almost every museum stuffed in a standing posture, which the living bird is quite incapable of adopting owing to the weakness of its legs; and the discovery that the cuckoo lays its egg directly into the nest seems so far to have escaped the attention of many curators, whose exhibits are based

on the contrary belief. There is no doubt, in fact, that the display of birds in museums, at any rate in Western Europe, leaves very much to be desired.

The museum which realised its true functions, so far as its bird collections were concerned, would give prominence to special exhibits illustrating in the most graphic form aspects of bird economics, protection, migration, adaptation, and the progress of such lines of research as bird-marking and the census. To a very limited extent this is gradually being done; but the special exhibit ought to be promoted from the status of a mere side-show to the main activity of the bird galleries, which should make it their business to keep the public vividly in touch with the efforts and progress of ornithology. They should aim at providing for identification purposes a faithful representation of every species known to have occurred or likely to occur in the surrounding country, not so much through the expensive medium of dusty and faded stuffed effigies as through a gallery of all the best figures, particularly coloured ones, which could be taken from available standard books and suitably framed on stands—a scheme which has been carried out with notable success at Haslemere Educational Museum, and perhaps elsewhere. Yet as we have already found, the exhibition galleries, enormously as they might be improved, are not the most important part of a great museum. It is not they but the study collections that really settle to which grade a museum belongs. In the British Isles there are probably only two which are by this standard of first-rate importance; one is the British Museum (Natural History) at South Kensington, and the other is almost unique in being a private

collection, the Rothschild Zoological Museum at Tring. Unique, that is to say, in being a private collection run on scientifically productive lines and forming a definite unit among the limited ornithological resources of Europe. Of course, Dublin and several provincial museums in the United Kingdom possess study collections of not inconsiderable extent, but with very few exceptions they are too understaffed to be able to do anything to further research. Apart from the British Isles, probably the most important museums, at least as centres of research, are to be found in the United States, Germany, and Denmark, but most of the so-called Nordic countries are more or less active in this direction. France and the Latin and Slavic nations (except Hungary) are considerably less so, and the Orient quite stagnant, with the conspicuous exception of Japan.

It is to the study collections that almost all specimens of real scientific value sooner or later find their way. Such institutions cannot, of course, compete with rich men of perverted tastes for the costly surviving specimens of the great auk and its eggs, but the mania for collecting is not strikingly hereditary. If the founder of a collection does not bequeath it to the public, his heirs (after disposing of any saleable items) are generally only too thankful to palm off the white elephant on any museum willing to accept it. Under this system decently labelled collections of any special interest usually go to the national museums, while the general ruck remains for the provincial, which, in their present neglected and understaffed condition, rarely deserve anything much better than the rubbish they usually get.

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CHAPTER IV

HOW TO OBSERVE

One cannot observe without a theory, and what seems the simplest of ornithological tasks—to go out of doors and look out for something worth recording—is in reality one of the hardest. Many people can collect birds, skin them, photograph them, draw them, mark them, count them, or describe their plumages with considerable efficiency, but real observers are very few, and there never has been an observer yet who was not very limited and obtuse compared with what he might have been. It is a mistake to imagine that complete impartiality and freedom from preconceived ideas is the qualification for a perfect observer. The cow is an animal with a remarkably open mind, yet it has never been found to reach a high degree of civilisation. Most bad observers probably approach the subject with much more open minds than most good ones. The reason is not that impartiality is an evil, but that in itself it is a complete bar to observation. To speculate on the unknown involves applying to it the inevitable bias of an ungodlike mind. Yet one must have thought about a subject, or at any rate about an allied one, in order to be able to notice anything at all detailed relating to it. Every day a great many ordinary people without any interest in birds are present when things take place which some ornithologists would give a great deal to watch, but these people not only

fail to record what they see, they fail even to see it, because they are not looking out for it and there is no place in their minds for it to fit in. A naturalist whose friends attempt to learn from him the songs of common English birds is shocked at first to discover quite intelligent people of good hearing repeatedly failing to distinguish accurately between the blackbird's song and the throstle's, or the chaffinch's and the robin's, which are to him as far apart as a dog's bark and a goat's bleat. The reason is that they possess at first no standard in their minds which will serve; it is easy to pick up quite rapidly the difference between two very similar strains when one is familiar with many, but the first half-dozen, however distinct, take a long time.

It is necessary, then, for the observer to be trained, and by *trained* something more must be understood than mere practice in watching birds without scaring them away. There are many people—the type is especially common among gamekeepers, shooters, and sanctuary-wardens—who have been watching birds all their lives and are nevertheless thoroughly unreliable on any but the most obvious questions of fact, not because they are untruthful, but because their minds have never undergone the discipline of testing each observation till it is proved to be quite sound and watertight, and of always being ready to meet expert criticism. The very conflicting detailed accounts which are often given in perfect good faith at an inquest into an accident or a crime are a familiar instance of the same shortcoming. And when we remember that every observer, whenever he investigates anything new, has to act first as a detective and later as a coroner or judge, the subjects

of his inquiry being incapable of giving any account of themselves and often unwilling even to be watched, it is not hard to realise why competent observers are so rare. They need not only keen faculties (or at least one keen faculty, either hearing or sight), training, and much patience, but some qualities of mind rarely found together—imagination, ability to know exactly when a thing is proved, a command of language, and some aptness in description, precision over facts, and something like fertility in theory, to mention only some of them.

It seems inevitable that first-rate all-round observers should always be too rare, but there is no doubt at all that the general level of observation, and the usefulness of the ordinary observer might be enormously improved. A multiplicity of lines of research held up for lack of the most simple data (which no one happens to have got), and, on the other hand, thousands of potential observers wasting their time on the futile recording of early migrants, albino sparrows, or chance vagrants on reservoirs and sewage farms—that is the unhappy spectacle which ornithology at this moment presents. The same is true not only of England, but *mutatis mutandis* of almost all parts of the world where anything is being done at all. Indeed, judging by the pioneer investigations along such lines as bird-marking and the territory theory, England, with the Teutonic countries of North-Western Europe, is the least backward, although in the important matter of a bird census, the United States has always taken the lead in large-scale operations. It is not, however, desirable to go into any detail here, the point to be made being simply that

there is no truth whatever in the easy and fatal belief that ornithology is almost worked out. That belief has persisted since a long time ago; it is amusing to find an author of Yarrell's period (1784-1856), in what we should call the Dark Ages of ornithology, apologising for his work on the same ground, and merely venturing to hope that, everything of importance being already known, he had presented the subject in rather a better arrangement than his forerunners.

Ornithology, as a matter of fact, has hardly begun; in this little book we are sketching the outlines of an incipient science rather than expounding the principles of an established one. The delusion that nothing remains to be discovered is the inevitable result of the false and perverted view of ornithology which was long current, and lingers even now. What was venerated yesterday as a standard work forming the Alpha and Omega of the study of birds will be regarded to-morrow as a mere collector's handbook, giving, without remarkable accuracy, the descriptions of species with their nests and eggs, the crudest account of their distribution, and practically nothing besides.

The first thing, then, to be borne in mind is that there is at the present time probably no part of the earth's surface, land or water, where there is not fruitful observation to be done. High altitudes, great cities, deserts, and ice-fields, like all highly specialised environments, are liable to a monotonous and perhaps very limited avifauna, but even these present to the observer with vision immense opportunities for constructive study. In towns, even the largest, which are generally considered hopeless by the average ornitho-

logist, there are more significant adaptations and more developments to be observed in rapid progress than in most of the famous show-places to which he is always yearning to dash off. Similarly, there is no bird in the world, not even the sparrow, about which a good deal of the first importance does not still await investigation, whenever an observer appears with the patience and the imagination to get to grips with it. In reality the field is so infinite that the difficulty is to avoid dissipating one's energies, and this applies equally to each individual worker and to the science as a whole, which is at present attacking the most intricate problems of migration, economics, and so on, with resources hardly sufficient to deal adequately with any one of them by itself. It is desirable, therefore, to take one line, or at any rate two or three lines and keep to them, rather than to act as an opportunist pursuing for a time whatever happens to turn up.

If you are at the stage when you can discern nothing worthy of note except a hawk striking down an owl, or a nest in a tin can, or a crow with a malformed bill, it will no doubt seem at first that this is a counsel of perfection condemning you to a very small return for your labour, but in practice it is not so. As you get deeper and deeper into your subject the remarkable events multiply, because all sorts of things dismissed as insignificant before, and many which were never noticed, take on a vital meaning. Thus the average observer will perhaps note the dates on which various species begin and cease their song, and the character of the song, and very little else, whereas anyone engaged in tracing the connection be-

tween song and territory will discover, if his hearing is good, a whole new world of primitive whispered sub-songs betraying the most unexpected likenesses. He will look out eagerly for any case of a bird singing its true song while still belonging to a winter flock, or for a hen bird uttering anything like song or sub-song, and for courtship accompanying song or preceding it. He will notice with surprise and almost incredulity how large a part is played by song in making the smaller and duller birds conspicuous at that stage of the breeding season when they have to be so in order to warn off rivals and to attract a mate, and how the song is often accompanied by a new habit of lofty perching, or of dancing in the air, which serves to reinforce this effect. In fact, once the observer is launched on the right track, every song he hears, even of the most abundant species, will become positively or negatively a valuable clue, and the most casual allusions to a song in books will become invested with a rich significance of which the writer was probably entirely unaware. The most trivial incidents, like two cocks of a territorial species perched on the same stone, become to the trained field-ornithologist data which may help to confirm or to modify a fundamental theory of bird life. It is true that the egg-collector shares with the true observer this absorbing interest in the apparently insignificant, but there is no comparison between them, for while the oologist gloats over eggs for eggs' sake, the observer is only interested in his facts precisely in proportion to the light they throw upon bird life—it is not the facts, but their aid in solving ornithological problems which form the attraction.

It is difficult at this stage to lay down any very satisfactory rules about observation, but certain principles are plain. The ornithologist should choose his field largely, of course, according to his own inclination (for he is likely to do best what most appeals to him), but also with regard to the resources of the area in which he lives, unless he has unusual opportunities for travel. Thus there are obviously some districts particularly suited for the study of bird communities, others for migration, others for the effects of sweeping changes in environment caused by building, droughts, floods, storms, agriculture, or drainage. It would not only be difficult to make any useful study of, say, communities, in an area where hardly any important social forms existed, but it would be waste of opportunity to follow in country specially favourable to one line of research a different line which could be done better elsewhere. On the whole, districts as compared with one another are not "good" or "bad" for birds, as most people believe, but merely different; the popular idea is due to the fact that everything is eternally being considered from one narrow angle of the pursuit of rarity. A "good" district is accordingly one which is attractive for that often harmless, but rarely useful, line of observation, and a "bad" district one which is not. The assumption only needs to be analysed in this way to show how ridiculous it is, and it brings about the paradoxical result that facts about rare birds are recorded in such disproportionate detail that often more is known about them, not only relatively, but absolutely, than about the despised creatures which haunt our own gardens and form the preponderant influence in

our wild life. It is probably no coincidence that almost all the observation of most permanent value, taking the case of England, has been done not in the "good" areas, along the coast and elsewhere, but by inland observers in remarkably "bad" districts for birds. Thus, Gilbert White worked on the edge of the Hampshire chalk mass, Jenner in Gloucestershire, Eliot Howard and Chance in Worcestershire; W. H. Hudson was tied down in London, while the Oxford Ornithological Society has been stimulated towards some pioneer efforts in corporate field work by the ordinariness of the South Midlands.

It is desirable, then, for the field ornithologist to pursue some fairly definite idea, selected partly according to his desires, partly according to the opportunities of the country in which he finds himself. He will rarely, however, be able to foresee at the moment of first being attracted to it how far it is going to lead him. To suggest schemes of observation hardly falls within the scope of this work, and the present writer has already attempted something of the sort in a previous publication (*How Birds Live*, 2nd edition, London, 1929). It seems, nevertheless, desirable to sketch very briefly a few of the problems most urgently in need of field inquiry which lie within the capacity of an ordinary observer without any special scientific qualification.

There are at present hardly any satisfactory data on the subject of non-breeding birds. It is well known that many of the larger forms do not assume mature plumage and begin to breed until the end of their second year, and even very much later, so that, however long they live, the non-breeding stock is bound to

form a large, and possibly the larger, part of the whole population at any given moment. The same thing may happen in the case of smaller species. For example, Mr. C. B. Moffat has shown reason to suspect it in the case of the European house-martin. But in any case there are always members of almost every species which, from one cause or another, do not breed, and at the vital period most ornithologists have usually been too obsessed with the hunt for nests to pay any attention to the question. We still do not know, either generally or locally, whether the army of non-breeding birds is permanent or whether it tends to disappear in favourable seasons and to increase in bad ones, nor whether there is a preponderance of one sex, and how far it may be responsible. It is a problem demanding patience and close observation at the right season rather than any special knowledge, since it might to a great extent be solved by a sufficient series of answers to such simple questions as these: Do all the local birds which stay through the breeding season attempt to breed? Assuming they do not, to which species and sex do any non-breeding birds observed belong? How do they live while the others are breeding, and what is their attitude towards the parent birds near them and to one another? Does the strength or composition of this non-breeding population vary at all from year to year? Has failure to breed any apparent connection with the status of the species concerned—resident or migrant, rare or abundant, territorial or communistic?

Or take competition. In almost every country there are instances of species either closely related or of similar range and diet, which seem likely to be rivals

for food-supply or nesting-sites, or both. Even where no visible hostility exists, one may gradually be replacing another through sheer economic pressure. Or one may have the advantage where the soil and vegetation are of a certain character, and at the point where it changes the advantage may pass to a rival. There are numerous suggestions that this sort of thing may occur, and may have important effects on distribution; it is impossible to say more because in scarcely any instance has the slightest attempt been made to work them out.

Again, there are certainly many cases of commensalism which have still to be detected before the subject can be considered anything but obscure. Commensalism implies species living together and gaining something by it for one party or perhaps both, without developing any sort of parasitic relation. Thus, while acting as ornithologist to the Oxford University Greenland Expedition of 1928, I found that along the coast of the fiord, where the arctic skuas (or jaegers) were quartered, the red-necked (or northern) phalarope was only to be found breeding in those swampy areas where a pair of ptarmigan had established themselves. The reason apparently is that any phalarope attempting to breed upon a skua territory would be doomed to destruction unless it could rely on the protection of the ptarmigan, which is the only local bird harmless in itself and yet sufficiently bold and vigilant always to repulse an approaching skua. In doing this, of course, the ptarmigan is concerned simply about the safety of his own mate and brood, without any regard for the helpless phalarope, but the phalarope, so long as it nests always within a ptarmigan territory, is able

to enjoy an immunity which it could never secure itself. There must be a good deal of commensalism among mixed flocks of different species, although very little has so far been detected owing to the meagre attention the point has hitherto received.

Again, many birds outside the breeding season resort to roosts a long way from their foraging areas. This is true, for instance, of many aquatic birds, and of such a widely distributed passerine species as the starling. Although a certain number of roosts have been observed, much more will have to be done in the way of tracing out fly-lines and mapping them locally in detail, before it is possible to say with any confidence what the factors are which govern the choice of roosting-places, from what distances their inhabitants are drawn, and what advantages a single great central dormitory has over the habit of roosting dispersed near the feeding grounds. Similarly, the foraging range of the communities which sometimes people a bird-rock, a marsh, a sandy spit, an islet, a lagoon, or a group of trees, needs to be carefully observed, in order to ascertain the real density of population over the whole area from which food supplies are being obtained, the powers of flight of the species concerned, and the extent of its contacts with other forms of life.

Fertility among different species varies most strikingly in different parts of their range, both as regards the number of broods and the size of clutch in each, and further, of course, the proportion of young reared. It is very necessary that a great many more data should be recorded on such points, as well as the proportion of eggs laid which are destroyed before and after hatching—that is to say, mortality in the nest—

and the causes of disaster, whether through human, animal, or climatic agency. This is chiefly a matter of statistics, and so overlaps with the bird census, with which, in fact, it may very advantageously be combined. To count all the birds on a small area of, say, twenty or forty acres and devote the breeding season to tracking down all their nests, recording how many eggs are laid and how many young reared, with the mortality details above mentioned, is at the moment one of the most valuable services which it is in the power of the ordinary observer to perform. On the other hand, a set of such details for all the nests which happen to be met with, not attempting completeness for any special area, is also of value provided one season is kept separate from another. The incubation and fledging periods of many of the commonest birds, even in England, are still very imperfectly known. Although it demands absolute accuracy and considerable care to establish the exact period without disturbing the subjects of inquiry, this is also an opportunity open to any student of birds without special qualifications. In taking up such a research it is desirable to record in as many separate instances as possible the date of laying of each egg, or indispensably that of the last egg, the date of hatching for the first and last chick, and the date of fledging—facts which must not be affected by any abnormal outside agency, or by the carelessness of the observer, if they are to be of any value.

Gregariousness, where it occurs freely, is always an interesting subject for study. The manner in which flocks come together, whether by the fusion of family parties after the breeding season or by the clubbing

together of bachelors or birds whose mates are sitting, or by the aggregation of newly fledged young simultaneously deserting their parents to form bands exclusively of the one year, or by the fortuitous concourse of all generations and sexes, deserves to be attended to in detail. Some flocks are freshly formed each day, and recruits can be watched joining the original members at intervals until it snowballs up to its full size. There is room for much work on the manifestations of this curious impulse in all birds which are in any way affected by it.

The local distribution of many species is exceedingly patchy and irregular; in some places they are common and in others, apparently of the same sort, they are entirely absent. There must be some reason behind this peculiarity, although none has been detected except in a few isolated cases. Often it may be due to competition, as has already been suggested, but that does not seem likely to explain nearly everything. Some work recently begun by the Oxford Ornithological Society suggests most strongly that geological conditions, acting no doubt through their influence on plants and invertebrates, may frequently be at the bottom of the mystery.

"The homing instinct" in birds has been the subject of a good number of experiments, many of a rather half-baked kind, but it has been little advanced by any of them, with the notable exception of the set conducted by two American scientists, Watson and Lashley, with sooty and noddy terns on Florida Keys. There seems no doubt that many, or perhaps all, species have a marked capacity for finding their way home over land or trackless water which they are most

unlikely ever to have visited before. This is especially conspicuous in the case of long-distance migrants which very commonly, though not always, return each breeding season to their native place, however freely they may have wandered since leaving it. But some preliminary experiments at the Oxford Trapping Station during the spring of 1928 showed that such a sedentary species as the greenfinch will return in a considerable number of cases from at any rate up to about nine miles in any direction. In the case of wild birds which have acquired "the trap habit" and are constantly being retaken, conditions are very favourable for testing—by removing them in closed receptacles to a suitable distance—how soon they will find their way back, if at all. But such work requires great care lest any point should prematurely be considered proved, and unless the experimenter is prepared to study the literature in order to learn what errors his predecessors have fallen into, and what difficulties they have met, he is unlikely, however much trouble he takes, to make any fundamental advance. Tests of bird intelligence are equally desirable on a large scale, but equally full of pitfalls.

It always seems curious to an ornithologist that so few ships' officers have taken up the study of birds with any enthusiasm. Very little accurate work is done at sea, although precise details of the distance from land at which various species occur, and anything throwing light upon times, seasons, or directions of migration would be of great value. It seems incredible that when the subject of birds crossing the Atlantic is of such scientific importance (at least half-a-dozen marked birds having already made the passage)

and at the same time of so much popular interest, that a bird can come aboard a liner which contains hundreds of unoccupied people, in mid-ocean, and be identified as a "duck" or a "sea-gull," as so often happens. The habits, food, and sometimes even the distribution of many birds found at sea are very inadequately recorded, and, of course, full details of any land bird occurring out of sight of the shore ought always to be noted. Even if there is no member of the crew with any interest in ornithology, some accurate standard work or a handbook like Alexander's *Birds of the Ocean* would insure that interesting migrants which actually rested on the ship should usually be satisfactorily identified.

The struggle for existence among birds is still remarkably obscure, and although the subject is by no means one of the easiest, any intelligent observer who concentrated upon it, in whatever part of the world, would be reasonably certain to discover something of value. He should devote his attention to accounting for the fate of the large surplus population which is usually in existence at the close of a breeding season, but has vanished, or been greatly reduced, by the middle of the next. He should try to ascertain what agencies operate on a large enough scale to have any definite influence upon the course of natural selection. For although it is assumed that large numbers of specialised characters are developed and kept efficient by a natural selection which ruthlessly weeds out those individuals in whom they are feeble or absent, yet, so far as birds are concerned, almost all this theory rests upon pure assumption. The work which ought to have been done to test in the field the Darwinian

hypothesis and its later corollaries, has not yet been set in hand. There is reason to believe that, however sound the theory may be in its most general terms, the nature of its special application to the living bird has been considerably misunderstood.

Enough has been said to show that the assertion that nothing remains to be discovered in ornithology is not entirely justified. In fact, if "everything" were substituted for "nothing" it would not be quite so wide of the mark. In this chapter only certain already apparent aspects of some of the more obvious problems with which we are confronted at the present time have been touched upon. If any attempt were made at completeness this little book would grow extraordinarily long, and it has to be remembered that in ornithology the solution of each problem reveals the existence of several others behind it. But no doubt any reader who may feel stimulated to play a part in the building up of ornithological science will find ample occupation for his energies among the lines of research just been pointed out.

Before leaving the subject of observation something must be said about ways and means. No costly apparatus is required, and the outfit of an observer is mental rather than mechanical, to be gained through practice and concentration instead of by monetary outlay. A pair of good field-glasses are the one article of equipment, not perhaps, indispensable, but at any rate valuable in most ordinary circumstances. While their pattern and power is to some extent a matter of taste and expense, probably the most serviceable for the normal observer are prismatic binoculars (which have a wide field of vision and good stereoscopic

quality), magnifying either six or eight diameters. There is little to be said for a lower power than 6x. The inexperienced observer is more tempted to choose the highest magnification he can afford to buy, but it has to be borne in mind that bird-watching is liable to involve the use of glasses for long periods at a stretch, and that unless the eyesight is exceptionally strong or the hand exceptionally steady anything above (or perhaps including) 12x will be found impossible to use without a cumbersome tripod. Moreover, the field at a thousand yards shrinks in proportion as the magnification increases, and binoculars which may be ideal for regarding a fixed object at leisure are often found to be less suitable for picking up a flying bird against a sky background. Some observers who devote much time to waterfowl and other not very restless forms, use a telescope to supplement an ordinary pair of glasses where the circumstances are appropriate. For the binoculars a leather rainguard fitting over the eye-pieces is valuable in most extremes of weather. Climbing irons in the case of difficult tree work or waders for marshy ground are almost the only other special things which the ordinary observer is likely to need; canvas "hides" are not commonly used by field ornithologists, except by bird photographers, although results might in some directions be improved if they were.

One thing remains more important than any of these paraphernalia of observation; an observer may do without field-glasses, but he can never do without a notebook. Most people have their own ways of taking notes, which are more often bad than good. To rely on odd scraps of paper and a pencilled scrawl is

nearly as bad as neglecting to keep any notes, and often more confusing. Some notes should be made in the field, but how fully depends entirely on the memory of the person concerned and other considerations, such as practice and the time which is going to elapse before they are copied into something more permanent. The permanent repository of notes should not take the form of a diary, or it will get out of hand as time goes on, and the references to any required subject will be very hard to trace. Something like a card-index or a loose-leaf ring-book is very much more sensible; it should have not only a heading for every species seen, but special headings for any particular point or group in which the observer is interested.

The final goal of the successful observation is that it should be published in the appropriate scientific journal of the country to which it refers, or to which the observer responsible belongs. In studying such literature, however well it may be edited, one is struck by the diversity in style, method, and outlook between the various contributors. Some hasten to send in their most trivial notes, others through diffidence, idleness, or too great caution fail to report things which are really significant and interesting. Some are terse, others verbose; some confine themselves to strict essentials, others allow themselves irrelevancies which may turn out of value to a worker on quite a different track, but this type is liable to leave out the essentials altogether. Some are very guarded in their identifications; others, and these perhaps the best, are a little apologetic and inclined to enumerate in detail the grounds for their decision; others are dogmatic and

peremptory. Some writers are controversial, going out of their way to provoke an exchange of brickbats, others are most careful to say nothing which could possibly offend anyone of any age or opinion. This diversity arises partly because ornithology as a science has still to find her feet, partly because ornithologists are for the most part amateurs (in so far as they are ornithologists and not professional bird photographers, writers, shooters, protection officials, or collectors) and are rarely trained scientists, but largely, of course, from a fundamental diversity of temperament. Almost the only thing that ornithologists have in common is that they never agree; whoever has taken any part in handling a British bird protection Bill will recognise that this is no smart paradox, but a mournful statement of fact, which must be faced in a later chapter. Amongst all this diversity of model it is clearly difficult to discover the true course. One thing is certain, that however much one indulges in swift provisional identifications in the field, no record should ever be sent in which stands the slightest risk of being overturned. If any doubt exists, always say so; it is better to point out an uncertainty over an identification oneself than to have attention called to it by somebody else. Moreover, the credit of any observer must depend very largely upon what he prints, and to be convicted of a blunder cannot fail to be a shock to it. In the field, on the other hand, although personal practice differs, it is quite legitimate among an unfamiliar avifauna to use tentative diagnoses, even if they are very likely to turn out wrong. It is easier to call something with definite characters by a name than to call it X, and a theory

of its true identity is easier to prove or disprove than a vague confession of agnosticism.

The ideal at which an ornithologist should aim is clearly that he should record sooner or later everything in his notes which is worth recording and nothing which is not. This implies for every observer a much better standard of values and a wider acquaintance with what others have already done than is usual at the present time. On the whole, observers do not read nearly enough about birds, at any rate of a fruitful sort; if they read more they would be able to observe to better purpose and to record with greater confidence and knowledge, so that through being more in touch with the main stream of ornithology they would contribute more largely to it.

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CHAPTER V

BIRD-MARKING

THE old-fashioned ornithologist was an individualist; and, as we have seen, there is a great field for individualism still. But the most striking feature of twentieth-century ornithology is the sudden rise to importance of organised co-operation. The first aspect of this movement to be considered is the growth of bird-marking. Marking in a crude form was practised occasionally in the eighteenth century, if not earlier, but it was first systematically employed with young woodcock on the Duke of Northumberland's estates at Alnwick in 1890. Very soon afterwards Mortensen began to develop it in Denmark with a scientific ability and success which has never since been surpassed. During the first quarter of the twentieth century other schemes sprang up all over "Nordic" Europe, and among the Slav nations it was pursued with conspicuous energy in Hungary and to a less extent in Russia. Very recently France has taken up ringing. There have been two or three British marking schemes, which were wound up some time ago, but much the most considerable, and the only one at present in operation, is the *British Birds* scheme conducted by Mr. H. F. Witherby. This has a large, though fluctuating, number of "ringers" working for it in many parts of Great Britain, and had succeeded from its inception in 1909 until the close of 1927 in dealing with more

than two hundred thousand birds. On the other side of the Atlantic "bird-banding," since it was first organised in 1920 by the Bureau of Biological Survey (a part of the United States Department of Agriculture), has undergone expansion on a typically American scale, so that it has now taken first place in point of numbers ringed annually, averaging at the present time about seventy thousand birds a year. This has also the distinction of being the only international effort in what should be an essentially international form of research, for Canadian as well as American observers take part in it.

Although a considerable variety of marking methods have been tried at one time or another, only the light metal ring has proved satisfactory. It is necessary that the medium used should survive as long as the bird which bears it; that it should carry a legible number, so that the individual history can be traced, and a legible full address for the finder to communicate with; and, finally, of course, that it should in no way hurt or inconvenience its bearer. Certain other methods which fulfil the last three conditions fail to comply with the first, so that the most interesting long-period records are most tantalisingly lost; it is difficult to find anything except the strip of aluminium alloy which can be readily bent into a regular ring to slide up and down the leg, and is at the same time light enough for the bird and durable enough for science. Nor is there much scope for variety in conditions of use. "Rings," or "bands," are usually issued in packets of ten or twenty consecutive numbers, accompanied by blank forms of schedules to be filled up as each one is used. These schedules have separate spaces or columns in

which are entered the date of marking, the number of the ring, the species marked, and, wherever possible, the sex and age (that is to say, whether adult, immature, or nestling), and the locality, together with the name of the marker. Most rings can be manipulated easily by hand, but a few demand pliers, and the larger sizes—for they are issued in different grades suitable for different birds—are often fitted with a clasp. At the end of each season, or when operations are finished, the completed forms, together with a list of birds marked, are sent in to the organiser of the scheme, who files them and sorts out recovery records accordingly.

Marking has been done, with surprising success, on a purely chance basis, the birds being released in the pious hope that at some other stage in their career, and most often at the end of it, they will again come to the notice of some human being who will see the ring and communicate with the address stamped upon it, giving details about its number and the place and date of recovery. If possible, its species and fate should be added, although the species can always be traced so long as the number is known. It is, of course, impossible to tell how many people who find marked birds fail to report them, but a great many are reported, the percentage varying from 0·1 per cent. in the case of very small short-lived species ringed in Great Britain to as much as 20 per cent. for Danish-ringed duck. Naturally, the recovery percentage is by far the highest in the case of birds which are much shot for food, or as supposed enemies to certain human activities. It is a not uncommon belief that there are men particularly on the look-out for ringed birds in order to shoot them.

This, of course, is entirely without foundation; successive recoveries are of such extraordinary value, as compared with single records, that no serious bird-marker would be willing to destroy the chance of them in this way, even if he were able. Moreover, a worn and tarnished ring is so nearly indistinguishable at any ordinary range, and the proportion of marked birds to the whole population always so minute, that any such scheme would be impracticable, even if anyone wanted to attempt it. As no bounty is commonly offered for the recovery of a ring there is certainly no inducement to the chance gunner to slay in the hope of securing one.

Yet the question of increasing the percentage of recoveries, and so making bird-marking more fruitful, is naturally one in which ornithology is interested, and the United States has given a lead in this direction by the establishment of a considerable chain of privately operated trapping stations scattered over an immense territory. It is one point of contrast between the New and Old World schemes that in America most of the birds marked are adults, but in Europe they are nestlings. Nestlings, of course, are easily caught and marked without any special apparatus, and have the notable advantage that a subsequent recovery is likely to throw light on their longevity, their return to the native place, the winter quarters of different birds from the same locality, and any cases of settling down to breed in a different country from the native one. In this respect the American system, which discourages the banding of fledgelings, appears open to criticism. On the other hand, marking of nestlings is wasteful, because so much of bird mortality occurs in the first

few months of life. Trapping is a notably economical method and gives a much higher recovery rate, since the marked individuals tend to remain in, or to revisit, the same locality, and a single bird may enter the trap fifty or a hundred times. There is, of course, a good deal to be said for and against each method, and it is probable that each is superior where it proves successful. In America, where predatory animals are much more likely to follow the trail of the observer to the brood which he has just marked, and where the ratio of human to bird population and the area of operations is on such a different scale, it is evident that concentration on nestlings is quite a different business from what it is in the British Isles. Moreover, the greater extremes of American climate tend to make trapping more efficient and fruitful than it is in the moist and mild English winters with their briefer spells of frost. Trapping can, of course, proceed at almost any season, but it is certainly most productive during severe weather.

When bird-marking was started, the migration question, largely through Gätke's fantastic dogma of 1890 that a small bird could cover long distances at well over two hundred miles an hour, was much more prominent than it is now, and, consequently, it was the obvious usefulness of ringing as a means of tracing journeys which led to its being so widely taken up. But the more bird-marking is practised, the greater its potentialities are seen to be. In summarising these various branches of its usefulness, it may be well to give a few examples of the sort of records that have already been obtained.

In the obvious sphere of long-distance migration there is a whole set of striking records. The Atlantic

is known to have been crossed by marked European birds on five occasions—twice by kittiwakes from England, twice by black-headed gulls from North Germany, and once by a Lake District lapwing—and from the American side once—by a common tern banded in Maine and recovered on the delta of the Niger. Greenland kittiwakes have been taken on both the European and the American side. A hundred white storks marked in Germany, Denmark, and Hungary, have been found in various parts of Africa, mostly down the east coast, and seven British-ringed swallows have occurred there, one on the Congo and six in the extreme south-east. Terns from the United States, including some of the more northerly parts, have occurred in the West Indies and South America; a Kerguelen albatross has been taken near Cape Horn after a seven thousand mile journey; and widgeon from England have occurred in East Russia.

Although spectacular, these records are at present too isolated, with one or two exceptions, to allow any very definite conclusions. But the masses of data which have been obtained are beginning to give a very clear picture of the movement of some abundant species between their summer and winter quarters—of the migrations of gulls, duck, hooded crows, rough-legged buzzards, and starlings from the Baltic countries; of lapwings, thrushes, duck, snipe, and many others from the British Isles; of grackles, gulls, duck, Canada geese, American robins, and others from North America. Of these the American results are, in some ways, the most interesting, being concerned with a large uninterrupted continent stretching through many degrees of latitude and a variety of climates. The manner in which some

species spread out fanwise from a compact winter quarter by the Gulf of Mexico over summer territory covering almost the whole width of North America seems particularly striking. Unless further data materially differ from those already issued by the Biological Survey in December, 1927 (Technical Bulletin No. 32 of the U. S. Department of Agriculture), the isolation of California and the Pacific coast region, which shows remarkably little interchange of population with the remainder, must also be ranked among the important facts of distribution which only bird-marking can bring out.

Longevity is one of the aspects of the life of a wild bird about which until very lately we knew nothing in particular. Even records concerning captive specimens are not nearly so abundant or accurate as one might expect, and the difference in diet and environment is generally such that they form a particularly treacherous analogy. But ringing, where it takes place on a sufficient scale, and the recovery rate is reasonably high, does allow us to form some idea of the length of a bird's life. When great numbers of American purple finches, juncos, " sparrows," catbirds, and chickadees (these last being conspecific with the European willow tit), or of European robins, finches, hedge-sparrows, buntings, and so on, are retrapped over and over again up to the end of their second or third year, and then much more rarely till after the sixth none occur, it seems a reasonable conclusion that the great majority must live only up to three or four years old. Some of the larger birds, however, seem frequently to reach ten or twelve years old, including the lapwing, heron (which has been recovered in its

sixteenth year), and various birds of prey—large gulls and duck. Although the newness of the American scheme makes it necessary to wait a few years in order to be certain, it seems that the expectation of life for a duck in America must be less than half what it is in Europe, owing, no doubt, to the immensely greater number of "hunters" on that side. The invariably low age at death shown by the latest American returns for this group is, at any rate, an indication of a way in which marking can help to supply data for the protection of game-birds on more scientific lines.

These are all aspects in which a great mass of results is necessary as a foundation to any reliable conclusions, but there are other directions in which ringing may be used to trace the life of the individual bird. By marking British robins with coloured rings, which rendered them distinguishable as individuals in the field, Mr. J. P. Burkitt has been able to discover a great deal about the mating and territorial relations, and the local movements of a most interesting species. It is clear that a considerable amount of similar work remains to be done for this and many other forms. To trace the pedigree and fortunes of one or more families through several generations is an obvious instance. A series of remarkable examples in Britain and North-Western Europe show that duck, and perhaps other birds which are native to one country, may "abmigrate," and be found breeding in another, up to thousands of miles away. Only the numbered ring could have brought this fact to light, and, as Mr. H. F. Witherby has pointed out, it may have an essential bearing upon the conspicuous absence of geographical race-differentiation throughout the group. If the stock

from one part of the range persists in interbreeding with the stock from another, it is clearly improbable that any divergence of type can occur.

As a final instance of the usefulness of bird-marking in unexpected directions, a raven casting found on the Oxford Expedition to Greenland in June, 1928, proved on analysis to contain some berries and remains of a daddy-long-legs, a humble-bee, and some small chick, together with a mangled but still just legible ring, which identified it as one of a brood of newly hatched purple sandpipers marked by a member of the Expedition a few days earlier within a mile of the same spot. Here the date of the casting and the identity of the victim could hardly have been discovered but for the presence of the ring.

Although it suffered a considerable set-back during the war bird-marking is now in the most flourishing state that it has ever attained to, and if the present rate of growth is kept up results on a really satisfactory scale ought to be forthcoming within the next ten years. Besides being one of the most potent of our methods of research it has the advantage of offering some opportunity for all who take an interest in ornithology to be of some service to it; either by acting as ringers themselves, or at least by being always on the lookout for recovery records, and by making the scheme familiar to all who are likely in the course of their occupations to meet with any marked birds.

CHAPTER VI

THE BIRD CENSUS

Some of the fundamental problems of bird life resolve themselves, upon analysis, into simple questions of numbers. The proportion of birds of prey to their victims, of any species to its competitors, and of the population as a whole to the food resources at its disposal, have a vital bearing on the economy and social organisation prevailing over a given area. We find by observation that the behaviour, even what we should have considered the psychology, of birds, alters in accordance with the density of population; they tend to be more truculent and quarrelsome where there are many in relation to the quantity of food or breeding space, and more tolerant where the pressure is lower. Both the territory theory (which traces how towards the breeding season many birds become strict individualists, claiming a private domain from which all others of their kind are rigidly excluded), and the study of economic ornithology (which is the indispensable basis for rational bird protection), demand a great deal of accurate census work before they can progress much further. The conditions governing the increase of communities, or of birds in any stage of organisation, are largely matters of statistics. In the last thirty years, therefore, line after line of observational research has found itself brought to a check, and has been forced to make some attempt to pro-

vide itself with numerical data in order to go forward again.

The growth of bird census work has been rapid and cumulative. Until the war very little was done, and that mostly in the United States and Germany. The United States Bird Census, organised by the Bureau of Biological Survey, remains the only national effort which has anywhere been made towards enumerating bird population as a whole. But it necessarily involved calling upon a good many observers unsuitable for such skilled work, and the use of rule of thumb methods, so that the isolated studies carried out elsewhere, particularly in Great Britain, often reach a higher standard of accuracy. It is doubtful whether as lately as 1925 there were above half a dozen persons engaged in scientific bird census work anywhere in the British Isles. By 1928, chiefly owing to the census of heronries undertaken in that year through *British Birds,* the number had risen to at least three hundred. At Oxford a corporate scheme of research has been in operation since 1927, but many more observers will have to be set working before the future of this investigation can be considered assured, and before data are available on a large enough scale to be of any permanent importance. While much excellent work has been done in America it is probably not unfair to say that the immediate need is to raise the quantity of census work in the Old World and the quality of it in the New.

A census may take several forms. It may be carried out by a single man on his own, or by an organised group repeatedly working the same limited area in order to secure comparative figures, as has been done

on the Oxford University Farm, or by a central office directing a number of observers scattered over the country. Its scope may include all the birds, of whatever species, which inhabit a patch of comparatively small extent; or it may be restricted to a single species or a small number of species, of a suitably conspicuous sort, and cover a much larger area, like the complete census of rookeries done in 1928 by Roebuck throughout Nottinghamshire, Derbyshire, and Leicestershire, or by the Oxford bird census over 224 square miles in the neighbourhood of Oxford. If the species is not too abundant and otherwise well fitted for it, the scope may be national, and the entire breeding stock of a given bird in a given country be made the object of inquiry, as was done in the *British Birds* census of heronries, and in Holland for the same species by Brouwer in 1925.

These different varieties of census are not only subject to different methods, but are directed towards different ends. A count of a single species over a large area is particularly bound up with an investigation into economic status (and of course into protection also, for the two are hardly separable). It will aim at bringing out any striking change in numbers or distribution, and when linked up with the results of an analysis made from an adequate sample of stomach contents (and castings, where those occur) it will be able to show with fair accuracy which sorts of food are consumed by the subject of the inquiry, and in what quantity. Thus, in the hypothetical case of a conspicuous bird which fed simply on corn, it would be possible to ascertain how much corn each individual got through in a week, and, by multiplying up to the

number revealed by census work, to show just how many bushels' toll were levied by that particular species. In practice, of course, there would be alternative forms of diet, some of which might work out in the interests of agriculture, and the proportion of each food consumed would vary at different seasons; such factors would complicate the problem, but they would not render it insoluble, provided the spade-work done on the census and in the laboratory were thorough. There is, however, an alternative reason for counting one species over a large area; such a species will probably be so wide-ranging, or communistic in its organisation, or both, that a complete bird census on any feasible scale cannot hope to do justice to it. The practice of including strong breeding colonies in a general census without their foraging grounds is much to be deprecated, since it can never give a true picture of the real density—that is to say, the ratio of bird population to the whole area supporting it. In any case, where this has to be done, the density should never be stated without the abnormal condition being pointed out. In a census where an area is first chosen and then all the birds upon it are counted without exception, the aim will be not so much to elucidate economic status, but to establish density, fluctuations, and the effects of competition, or if it is sufficiently intensive, to investigate the relations of each pair to their territories and to one another. The detailed study of a small piece of ground is also valuable for bringing to light all sorts of intricate and often substantial local movements which might not otherwise be suspected.

A further type of census, less ambitious but useful

in the absence of more thorough work, is the arbitrary cross-section through a wide extent of country. It may be carried out on foot, and may take the form of a transect of mountain-slopes through the various animal and vegetable zones, such as has been done by the present writer in the Alps from about 2,500 to 10,000 feet elevation, or of a count from the train, or from a ship at sea. In any case it is indispensable that the distance over which the count was made should be recorded, together with the time of day, weather, speed of motion, and anything else likely to have affected the figures. A division into sections is often convenient.

The accuracy of a bird census varies greatly according to the conditions of site and avifauna, and the experience of the observer. For a single suitable species, or for all species over a sufficiently open area of up to about ten square miles as a maximum, it may probably be brought within an error of two per cent. with the aid of a double check. Generally speaking, the proportionate error will diminish as the size of the area undertaken increases, up to the point where it begins to pass beyond the observer's power to keep pace. The explanation of this fact is that transient visitors, and overlapping of boundaries, are a much more serious matter in a small area than in a large one.

It is in many ways a misfortune for the development of the bird census in Europe that there is no sort of central body interested, or in any way responsible for it. Obviously there has to be, if not rigid control, at any rate some form of general guidance if the most is to be made of opportunities. Observers need direction,

and must be prevented from overlapping unnecessarily; without some recognised clearing-house it is going to be hard to make the data which have been secured available where they are needed, since their publication, even at this stage, would inundate all the available scientific journals to an impossible extent. Moreover, it is essential that there should be some standard laid down, so that results may be made comparable; not only laxity on certain points, but the mere use of a diversity of methods, however good in themselves, will seriously detract from the value of the work done.

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CHAPTER VII

BIRD PROTECTION

It is agreed in most civilised countries that birds, or at any rate some of them, ought to be protected against human persecution. But in spite of international conventions no sort of agreement has been reached in practice upon the protective measures which ought to be taken, or even the principles upon which they should be based. Canada and the United States have an understanding with regard to migratory species, but repeated efforts to secure something of the same kind in Europe have always come to grief. One of the most backward of all countries is Great Britain, where legislation which ought never to have been passed (and which everyone concerned has been trying for at least twenty years to repeal) remains nominally in force, owing to the irreconcilable differences of opinion, not only among interested parties, but among ornithologists of all kinds. These differences of opinion are due to the fact that while most of those concerned have met with the problem, and have thought out a specific remedy for particular evils, few or none have gone into the principles of sound bird protection, or attempted to obtain the data necessary in order to know the precise status of the forms to be protected.

It is clear that protection may be based upon a variety of ideas. It may, for instance, be based on

economic usefulness or the reverse. In that event, unless the law is to be drafted simply according to the prejudices of ignorant and interested classes, it will be essential to inform ourselves beforehand on the facts which are to determine the legal status of each species. That is to say, we must have, instead of a handful of stomach contents with large quantities of opinion and hearsay thrown in, a complete investigation covering all parts of the country and all seasons; reinforced by a reliable census telling us within a reasonable margin the actual numerical strength of the species with which we have to deal. Or protection may be based on the idea of compensation. It may represent an attempt to counteract the effects of human encroachment by safeguarding the surviving stock of the species affected, forbidding interference with their nests and eggs, and, possibly, where their breeding area is compact enough, setting aside a sanctuary or reserve for their benefit. In England, so far as any principle at all has been followed, this has proved much the most popular. It has the advantages of not demanding any action until the eleventh hour, of providing repeated opportunities for exploiting the sentimental aspect, and of enabling various rather decrepit and more or less well-meaning societies to pose as the apostles of bird protection, without making themselves unpopular among any section of their supporters.

It hardly needs a scientific investigation to show that a bird which has fallen from general abundance to a mere handful of pairs is in need of special protection. But it is always assumed, and not always with justification, that the regulation of deliberate

human interference must necessarily make some difference to the numbers of the species involved. It is from that standpoint quite useless to protect any form which has not hitherto been suffering from persecution. In most countries there are a great many small birds which nobody takes any notice of; to put them in a statute may look well, but it will not affect their numbers, because man is no more than a negligible factor among their enemies. There are, in fact, probably comparatively few species, except among certain Latin nations, which are capable of being appreciably multiplied by the grant and enforcement of the most generous protection. A few finches which are coveted by bird-catchers; a few farm pests, real or supposed; a few which are shot as enemies of game or fisheries, and those which interest the wild-fowler will probably exhaust the list.

There are, of course, other methods of protection besides the mere prohibition of destruction. Not only enemies, but a shortage of nesting-sites, of water, or of food may be the principal obstacles to expansion, and measures to remedy any defects of this sort may lead to a spectacular rise in the bird population, such as has been seen locally in many countries, perhaps most notably in Germany and the United States. It is a question how far such artificial stimulation is desirable in the long run. To put down food on a large scale in the nesting season, as is said to be done in America, is clearly an unwise system, since that season always more or less coincides with a more than average abundance of natural food. To supplement these resources, if it has the desired effect of increasing the breeding stock, must lead either to artificial feeding

on an even larger scale during the remainder of the year or to a most appalling discrepancy between the number of birds reared and the number which have any prospect of survival. Moreover, the moment such methods are adopted, the psychology of poultry-farming begins to enter into the situation, at any rate on the human side, and we find an almost irrepressible itch to destroy any species of predatory or parasitic habits which is seen to harry the carefully fostered community. The result, unless some extraneous factor can avert it, must be to bring about such a density with so low a standard of selection, that the latent parasites will soon get out of hand, and a terrible mortality will sweep through this artificial community, leaving it in a thoroughly enfeebled state and far below the normal level of numbers from which it aspired to enfranchise itself. The perils of this sanctuary system of protection are not sufficiently realised in England, and apparently still less in America; far-seeing bird protection must aim at a stable population living under natural stresses and not at a pampered community temporarily released from their operation, only to suffer in the long run a disastrous retribution.

The supply of water, on the other hand, simply remedies a chance natural defect confined to a very limited area, and seems open to no objection; while nesting-boxes and other artificial breeding-sites, although they tend to avert an undoubtedly healthy competition, can be furnished in any reasonable numbers without any apparent risk of undesirable consequences. Erection of nesting-boxes, planting of suitable cover, and other measures to enable birds to breed without unreasonable disturbance, seem, in fact,

to be the only legitimate scientific means of increasing a bird population which is already immune from human enmity. Certainly such methods do not involve any short-sighted tampering with the check imposed through the food supply, or through the activities of birds and beasts of prey. The gun is never a defensible weapon of bird protection, except in such very extreme cases as when the meagre remnant of some small, weak species is faced with imminent extinction, and is clearly suffering severely from the presence locally of a strong natural competitor or enemy. But any system of bird protection which logically leads up to the shooting of some forms in order to multiply others is clearly on a par with game-preserving. This point was emphasised in the present writer's *Birds in England,* published three years ago, and has nowhere been contested, although a large number of bodies responsible for bird protection in all parts of the world continue to act contrary to the true principle in their everyday practice. To bring bird protection, both in its legislative and popular aspects, more nearly into line with the findings of ornithological research, is one of the most urgent concrete tasks to be taken in hand by students of bird life.

Protection in most countries is a matter partly of law, partly of sentiment, partly of interest. To take some English instances, the lapwing and the great-crested grebe owe their protection, so far as it is effective, mainly to the force of law. Convictions for shooting them are probably frequent enough to form a certain deterrent. The robin and swallow, on the other hand, are much more powerfully defended by a

deep-rooted sentiment, and by public opinion, than by any legislation applying to them. To be known as a killer of such birds would in most cases involve a very real unpopularity, which few would care to incur. The pheasant, on the other hand, would get short shrift but for the power of the interest behind it, which controls not only the local magistracy sitting in judgment upon offences against the game laws, but the local economic community to which most potential offenders belong. This, of course, is an instance of a bird protected from slaughter by some people in order to be slaughtered by others, but in some parts of the world there are instances of an interest requiring the absolute preservation of certain species, like the secretary bird of South Africa or the carrion-feeders of certain tropical and Oriental cities.

In considering bird protection it has always to be borne in mind that a species can never be isolated from the natural association or community of which it forms part. Thus, there are communities of farm-birds, of woodland or forest birds, of marsh birds, of shore birds, of ocean birds, and many others in all parts of the world; and each of the members of these is to be judged not only by what it does itself, by direct consumption and otherwise, but by the part it plays in maintaining the general balance. Thus it is quite possible for a bird to be exclusively harmful, judged by its food analysis, and yet deserving of full protection owing to the much more serious evils which its extirpation would induce, and, of course, *vice versa*. We hardly possess full enough knowledge yet for definite examples, but the case of the starling, which has now become definitely more injurious than

beneficial at certain seasons in many parts of the United Kingdom, while appearing quite obviously beneficial in the United States where it has been introduced, will give some idea of the complications involved. If, as seems possible, the starling and some other species begin as useful birds but, multiplying rapidly, change their diet and become a pest, then it might be advisable to nip such an introduction in the bud, provided that would save native species of less prolific and omnivorous tendencies, which could be trusted to maintain a steadily beneficial economic status.

The general principle which seems to emerge, so far as present information allows us to come to any conclusion, is that instead of trying simply to protect birds we know to be useful, we should protect all except those shown to be injurious, with, of course, some seasonal suspension in the case of forms which are locally reckoned as game. Few protection enactments have hitherto shown the essential merit of simplicity; the law must be clear, for it is inevitably a law which closely affects many uneducated people, and it cannot be expected to work well unless they can understand it. For any other country but England, it is perhaps unnecessary to add that protection ought to be national in its scope and that a series of orders differing completely in every county will be childishly simple to evade. That does not, of course, rule out the temporary and local suspension of protection in the case of a single species or group wherever for some reason it is considered desirable, but on the whole the basic legislation should apply without discrimination between one district and another. Some means

will have to be found of exempting from penalty birds-nesting by schoolboys, wherever it is at all widely practised, and licences will have to be granted in carefully defined terms to genuine students pursuing a line of research which demands special facilities. With these exceptions, the protection of nests and eggs of all species not expressly black-listed will have to be rigidly enforced, until the destructive and unjustifiable money traffic in stuffed birds and egg-shells for private collectors, and the haphazard destruction of rare forms from ignorance or hope of profit, has been effectively suppressed.

Bird protection, if it is to avoid serious reverses, must not aim at unduly increasing numbers, except where they have demonstrably been reduced. It must set out to salvage species whose existence has been put in jeopardy by the squandering destruction of the last six or seven generations, to preserve a normal and enduring balance of nature, to simplify the task of the observer, and to increase the pleasure of all and sundry by gradually removing the lack of confidence which birds feel in mankind.

CHAPTER VIII

THE FUTURE OF ORNITHOLOGY

The more one considers the ornithology of the past the more one must turn to the future. With so many problems exposed and so few followed up, so much set in hand and so little conclusively achieved, it is natural that a wide acquaintance with bird literature should lead to incessant speculation on the course of this curious science, and an impatience to remedy the lack of data which is everywhere making its starving influence felt. It is clear that ornithology is now, and always has been, so short-handed that adverse criticism of its efforts may seem distinctly ungracious, yet, on the other hand, it enjoys as wide a popular interest as almost any branch of science and the number of potential observers who might be enlisted is colossal. Practically all this potential assistance is allowed to run waste because ornithology has never possessed the means of harnessing it, and because so few, even amongst those who are called ornithologists, have any clear vision of what needs to be done. The immediate necessity is not so much to expand the ranks of the observers as to direct into more profitable channels the energies of the not inconsiderable number of observers who are already at work.

The day of the individualist observer as the typical, and almost the only, representative of ornithology is undoubtedly past. He may, and certainly should, have

a glorious future in store for him. We have reviewed in a previous chapter some of the lines of research which still await his attention, without attempting to be exhaustive, or to deal with such important and absorbing subjects as courtship and display, and the intricacies of the territory theory. These are too complex for treatment in a work of this scope, and are dealt with in some of the works cited in the Bibliographical Note (page 77). As an experimenter, also, he has a wealth of unexploited opportunities, but here, owing to the number of traps for the incautious, trained scientists must usually enjoy a monopoly. The work which is being done by Rowan in Canada on photo-periodism as a factor in bird migration, or by Thienemann in Germany in narrowing down the migratory impulse in storks, are indications that the possibilities of controlled experiment are not being altogether neglected.

The individualist in the future must be only a part of the strength of ornithology; there must be a large and sufficiently organised corps of observers, co-operating for the solution of definite problems laid before them by some central directing body. In America the United States Biological Survey has undertaken these duties so far as it has been able, and the success there met with serves to show up the chaos in the European countries. It is almost incredible, in view of the great economic importance of birds and the light which their study can throw upon other obscure aspects in nature, that there is still no Institute of Economic Ornithology in the United Kingdom, nor even any endowment at any university to assist the study in any way. Hungary, which is not

considered a violently progressive country, has possessed such an Institute for a long time, and it is obvious that until the Ministry of Agriculture, or some private fund or persons, rise to the occasion by founding some centre for ornithological research in the British Empire, little progress can be made towards the co-ordination so urgently required. Even if other European countries establish centres on their own, they cannot secure the help from British ornithology which they have a right to expect, until a whole-time, well-paid, and well-trained staff is in existence to guide the energies and digest the data of observers in the British Isles. An Institute, presided over by a competent ornithologist, but containing also an entomologist, an expert of agriculture, and another on plant ecology and botany—with some provision for keeping contact with forestry, research upon fisheries, and so on—would, provided it were directed with sufficient initiative, pay its cost over and over again by reducing the depressing waste and dissipation of energies characteristic of the present stage of ornithology, quite apart from the results which its special investigations ought to bring. That it should be left to private observers to face the gigantic business of undertaking volumetric analysis of stomach contents on a national basis is only less incredible than the fact that a few courageous investigators, notably Dr. Collinge, of York Museum, have been found willing to try their hand at it, albeit on so relatively small a scale that nothing conclusive can be hoped for until things are put upon a more reasonable footing.

Ornithology will have to organise itself, not as it has been content to do in the past, through friendly

societies better fitted for mutual admiration and pleasant converse than for any more active utility, but under working Institutes. One might be provided for each country, or, where circumstances permit, for each region or group of countries, each having, if not actual control, at least a very strong moral influence in directing the course of research, and in ensuring that the resources and energies at its disposal are used with the maximum effectiveness. This is not to say that all or even any existing bodies need be wound up or superseded, nor that the national supremacy which has been established by such associations as the British Ornithologists' Union, the American O.U., the Royal Australasian O.U., and so on, in their respective territories, ought in any way to be touched. The new co-ordinating bodies would be supplementary, and would restrict themselves to their obvious duties in the field of research; they might well be subordinate to the all-inclusive organisations which have just been referred to. The desirability of having an authoritative clearing-house for observers, such as is formed by the British Museum and similar institutions abroad for systematists, is so obvious that such a development would be as likely to receive a general welcome as anything new in ornithology could expect.

It will be necessary also to undertake a vigorous campaign to shake the local natural history societies and field clubs out of the apathy into which they have mostly sunk, and although this applies particularly to Great Britain, it is true also of other countries. Too many of them have fallen into the hands of an elderly and passive group of amateur naturalists with obsolete ideas and next to no initiative. For this the younger

members are often largely to blame, since they have displayed remarkably little initiative themselves. Almost all societies, even the busiest and the most urban, could undertake some limited but valuable scheme of corporate observation. If they would make the effort many could without much difficulty run an organised trapping station, requiring only about ten participants, of which at the present time there is only a single example in England. Many of these local societies publish transactions, or similar periodicals, the value of which is sometimes very small. It has been pointed out by Mr. Charles Elton that the best of the small regional journals are usually those associated directly or indirectly with some university or big museum, which suggests a line for future development. A good many existing publications of this sort might advantageously be combined.

The supply of future ornithologists should not continue indefinitely to depend, as it has in the past, on the chance of a small number of birds'-nesting boys growing up to take an interest in other aspects of bird life. School natural history societies ought to be in touch with similar associations both regionally and at the universities, so that leaving members who are sufficiently interested may readily be transferred from one to the other. The whole question of biological training is at present in a state of flux, owing to the fact that education has failed to keep pace with the recent expansions of professional biology; but there is reason to believe that the next few years will see a general revision at the expense of the older sciences, notably in the English public schools, and from such a development ornithology stands to gain. One of the

great obstacles which have hindered its balanced development as a science has been that almost all the paid posts concerned with it have supported only systematic and anatomical zoologists, who, working in their museums, have until quite recently been prone to ignore or belittle the observer in the field. Now that systematy is sufficiently cleared up for the balance to be shifting the other way, it ought to be possible to secure for research in the field something like the nucleus of trained zoologists which it needs. In this connection it is worth noticing that almost all the more fruitful observations for a long time (again so far as Great Britain is concerned) have been due to non-scientists. The territorial habits of the robin have been exposed chiefly by a county surveyor and a retired Cabinet Minister; most of the other work in that direction has been done by business men in their spare time. Although the results of this amateur research have proved remarkably good, those who have taken the chief part in it would be the last to deny that trained zoologists who have outgrown the old obsession with systematy and purely laboratory work will be a valuable addition to their ranks.

It is not to be concluded that the rationalisation of ornithology which has just been pictured will destroy the liberty of the private worker in any way. In fact, just as Man in the mythical State of Nature can have no rights, and therefore no real liberty, so the ordinary observer is inevitably tied down in a state of unimaginative bondage to the fetishes of an outworn conception, until some steps are taken to reduce the science to order and to clear for him a path which he may profitably explore. Ornithology has never

been so widely popular as now, nor so acutely conscious of her ignorance and her shortcomings. Given the vision, the energy, and the patience to direct her efforts in the right way, she is assured of a future very much more fruitful than her past; whether she will attain it without much spendthrift activity and unjustified delay rests with the observers of the present generation.

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BIBLIOGRAPHICAL NOTE

THE bird literature of the world is a colossal subject, and in this brief note it will not be possible to cover, even in the most summary manner, anything like the entire ground. Having regard to the fact that this is primarily an English work, the majority of the works cited must be in English; this, however, is not altogether unrepresentative, since the majority of important publications in recent ornithology have been in that language. Further, since this little book is scarcely intended for specialists, popular expositions of a reliable but non-technical sort, especially those containing bibliographies, must have the most attention.

On the general biology of birds, a subject only to be tackled in a fairly large work with unlimited illustrations, some excellent books are available. Of these Professor J. Arthur Thomson's sound and lucid *Biology of Birds* (1923), from a European standpoint, and William Beebe's brilliant popular exposition in *The Bird* (1907), from an American, are the most to be recommended.

There is no history of the birds of the world, and only single groups have hitherto been at all exhaustively treated from a cosmopolitan standard. Among these William Beebe's *Monograph of the Pheasants* (1918-1922), J. C. Phillips' *Natural History of the Ducks* (1923-1926), and, as a pocket handbook, W. B.

Alexander's *Birds of the Ocean* (1928), may be cited as good recent examples.

Taking regional works, Dr. E. Hartert's *Vögel der Palaarctisken Fauna* (1903, etc.) has superseded Dresser's *History of the Birds of Europe* (1871-1896), but is written in German. For ordinary purposes, Wardlaw Ramsay's *Guide to the Birds of Europe and North Africa* (1923) is a very convenient work which will go in the pocket, but it has its limitations, is in some respects out of date, and on questions of distribution not remarkably accurate. The standard work on British birds is H. F. Witherby's *Practical Handbook of British Birds* (1919-1924), in which the level of accuracy is extraordinarily high, but the various plumages are given in so much detail that, apart from points of distribution, T. A. Coward's compact *Birds of the British Isles* (1922)—especially the first two volumes, the third being a somewhat disjointed collection of addenda—will be more useful to the ordinary observer. It contains a good range of fairly faithful coloured plates, and a good deal about habits; for the most complete treatment of these last, reference should be made to F. B. B. Kirkman's *British Bird Book* (1910-1913) which, like Witherby's, includes contributions from a set of leading specialists. Thorburn's *British Birds* (1926) is more of a picture-book than a comprehensive ornithology; the pictures, however, are often very good indeed. A marvellously cheap identification book, and much the best of its sort, is Kirkman's shilling *British Birds* (4th ed., 1928), in the "People's Books" Series. Naturally, the rarest forms are not included, but it gives everything at all likely to be met with, and the descriptions are terse and accurate. It is

clearly impossible here to attempt discussion of local avifaunas outside Europe, although good works exist, in more or less variety and detail, for most parts of the world. The various encyclopædic works on birds, such as volumes in the *Cambridge* and the *Royal Natural History* are generally good as far as they go; Professor A. Newton's *Dictionary of Birds* (1893-1896) is long out of date, and there is no current work covering quite the same ground.

For tracing references to local British avifauna *A Bibliography of British Ornithology* (1916-1917), by W. H. Mullens and H. Kirke Swann, must be considered indispensable.

The Origin of Birds, by Gerhard Heilmann, and *Problems of Bird Migration,* by Dr. A. Landsborough Thomson (both 1926), are thoroughly sound works on the subjects apparent from their titles. *Animal Ecology,* by Charles Elton (1928), treats from a general zoological standpoint the relations between various animals (including birds) in a social and economic sense; the same subject is treated purely ornithologically in the present writer's *How Birds Live* (2nd ed., 1929), which contains appendices summarising recently published and unpublished data, including bird census results. There is no book devoted to this last subject, or to bird-marking, although Landsborough Thomson (above cited) gives quite a good account of it incidentally. The only book on bird protection in the British Isles is the present writer's *Birds in England* (1926), which includes a fairly full account of historical fluctuations in status. *The Food of Some British Wild Birds; a Study in Economic Ornithology,* by Dr. W. E. Collinge (2nd ed., 1924-1926), represents very nearly the sum of

our present knowledge upon its subject. In America a very complete summary and bibliography of the subject has been furnished by Professor J. Henderson's *Practical Value of Birds* (1927).

On observational methods, besides many of the foregoing works, those of Edmund Selous, W. H. Hudson's *Birds of La Plata,* and others, William Beebe's books and his papers in *Zoologica;* Julian Huxley's notes on the " Courtship of the Great Crested Grebe " in the *Proceedings of the Zoological Society of London* (1914), and on divers in *Spitsbergen Papers* (Vol. I.), may be cited as good models.

Every country in which ornithology is at all active has a scientific journal with which all serious observers should be in touch. In England the *Ibis,* the official organ of the British Ornithologists' Union, has a worldwide scope, while *British Birds* (edited by H. F. Witherby at 326, High Holborn, London, W.C.1) is the nearest approach to a clearing-house for observations. The *Scottish Naturalist,* and the *Irish Naturalists' Journal,* of Belfast, cover the smaller kingdoms; while the *Journal of Ecology* (Oxford) deals with interrelations between fauna and flora from a wide angle. *The Journal für Ornithologie* in Germany, *The Auk,* and *Condor* in America, *Emu* in Australia, *Ardea* in Holland, *Danske Fugle* in Denmark, *Gerfaut* in Belgium, and *Revue Française d'Ornithologie* in France, may be mentioned among the many specialist periodicals all over the world.

POISONS

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POISONS

AN INTRODUCTION TO TOXICOLOGY

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POISONS

CHAPTER I

HISTORICAL

"Of all the branches of medicine, the study of toxicology is that which excites the most general interest. The naturalist examines the varied forms of poisons and arrives at a method of pointing them out. The physiologist seeks to explain their mode of action. The physician directs his attention to the search of means capable of destroying their action. The chemist brings to perfection the process necessary to enlighten the magistrate whose duty it is to punish the guilty. The private individual is fond of discoursing on the properties of poisons; he never ceases to deplore the fate of the victims of negligence or mistake, and to feel for the unhappy wretches whom despair has hurried on to suicide; incensed at the most cowardly of crimes, he regards with horror the execrable assassin, and loudly demands his punishment."—ORFILA, A.D. 1814.

ORFILA is the father of modern toxicology. Since his day the subject has gained immeasurably alike in importance and interest by reason of the incessant march of science, the multifarious uses of poisonous substances in peace and war, and legislative restrictions. An insight into this branch of knowledge is an every-

day essential of medical practice, and by promoting the welfare of the community it is a valuable equipment for the lay citizen.

Allusions to poisons are found in very ancient writings. A passage in an extremely old papyrus in the Louvre has been interpreted: "Pronounce not the name of Yao under the penalty of the peach"; which implies that the Egyptian priests were acquainted with prussic acid prepared from peach kernels. Greek literature abounds in poison lore. Homer (*cir.* 1000 B.C.) relates that Ulysses sought to obtain a poison with which to anoint his arrows. Xenophon (*cir.* 400 B.C.) says the use of poison was so frequent among the Medes that it was a custom for the cupbearers to taste the wine before presenting it to the king. The most famous case of poisoning in classical times is the death of Socrates (399 B.C.), which showed the use of hemlock as a means of execution. Plato's description of the drug's action is so accurate in its detail that it will be quoted later, in the chapter on hemlock. Theophrastus in his *History of Plants,* written about the year 300 B.C., makes many references to poisons. The earliest works extant treating specially of poisons, the *Theriaca* and *Alexipharmaca* of Nicander (185-135 B.C.), display a wide knowledge of poisons. The search for antidotes, which no doubt coincided with the discovery of the dangers of poisoning, led to the idea of antagonising one poison by another. A physician invented an antidote, which he recommended to Mithridates the Great (132-62 B.C.), whose acquaintance with poisons was a frequent topic in classical literature; his famous antidote, *theriaca,* according to Celsus, contained thirty-six ingredients.

In Roman history the earliest reference to criminal poisoning was in 331 B.C., when a considerable society of women poisoners was discovered, and many of the members were executed by poison. The first legislation against the crime was passed by Sulla in 82 B.C.,

and it continued in force until the fall of the Empire; the punishment was exile and confiscation of property, or exposure to wild beasts. One of the finest orations of Cicero was his defence of Cluentius (66 B.C.), who was charged with poisoning. In the times of Augustus, Tiberius, and Nero, professional poisoners were employed for political murders, and the crime was so rife that Agrippina refused to eat of some apples at the table of her father-in-law, Tiberius. A criminal of the period in the service of Nero was Locusta, by whose agency the deaths of the Emperor Claudius and Nero's brother Britannicus were compassed; she was executed in the reign of Galba.

Dioscorides (A.D. 40-90) has left a great work on *Materia Medica,* including a treatise on poisons and their antidotes; he placed poisons in three classes—animal, vegetable, and mineral; his lists include cantharides and snake venom; opium, hemlock, henbane, and aconite; arsenic, lead, and mercury. From the Greek word *toxikos* ("for the bow"), he applied the name *toxikon* to the poison smeared on arrows, whence is derived the modern word toxicology.

In the Middle Ages it would appear that secret poisoning was a not uncommon crime; and it is certain that the deaths of a number of emperors, popes, and other historical personages were currently attributed to this cause. It is recorded of Charles the Bad of Navarre that he directed a minstrel named Woudreton to purchase arsenic and poison Charles VI. of France and his uncles by mixing it with their food or drink. Woudreton was detected and executed in 1384. With the Renaissance, assassination by poison became a notorious crime on the Continent, and there are many records of the guilt of the heads of states, as well as of private persons, impelled by cupidity or revenge. The secret archives of the Council of Ten at Venice prove that political murder by poison was considered a legitimate practice. Many of the murders

attributed to Pope Alexander VI. (1492-1503) and his son Cæsar Borgia were effected by poison. Nemesis overtook them when the pope's butler served the poisoned wine intended for others to Alexander and his son; the pope died, and Cæsar only escaped death at the cost of a severe illness.

Nor was the crime unknown in England, where the secret poisoner was regarded with special abhorrence. In 1531 a statute of Henry VIII. ordered that convicted poisoners should be boiled alive. Wriothesley's *Chronicle,* A.D. 1542, states: "This yeare, the 17th of March, was boyled in Smithfield one Margaret Davie, a mayden which had pouysoned three householdes that she dwelled in. One being her mistress which dyed of the same, and one Darington and his wyfe which she also dwelled with in Coleman Street, which dyed of the same, and also one Tinleys which dyed also of the same." In the reign of James I. a quack named Lamb, who was believed to have furnished Buckingham with poison for a nefarious purpose against the king, was seized by the populace in Cheapside and beaten to death.

But it was in Italy and France that a system of poisoning spread like an epidemic, and despite the rules of the confessional the clergy felt bound to disclose to Pope Alexander VII. the extent of the evil. Many of the victims were men, and investigation led to the discovery of a secret society of women which met at the house of Hieronyma Spara, a reputed witch, who supplied those who wished to get rid of their husbands with a tasteless poison graduated to kill quickly or slowly; presumably a solution of arsenic. La Spara and thirteen of her confederates were hanged, others were flogged publicly in Rome, and some were banished. Some years later discovery was made of a similar society at Naples, where a woman named Toffana sold an arsenical liquid termed *acquetta di Napoli.* Her victims are said to

have numbered more than six hundred; she was executed in 1719.

Contemporary with these Italian women poisoners, the crime was very prevalent in France. Here, too, the agents were married women, and disclosure was made by the Catholic clergy. The manufacture of poisons at Paris was traced to an Italian named Exili, who was associated with a chemist named Glaser, the author of a book on chemistry. Exili was imprisoned in the Bastille; a fellow-prisoner was Captain Sainte-Croix, lover of the beautiful but unprincipled Marquise de Brinvilliers, the echoes of whose sensational trial for poisoning are still audible (see Lord Birkenhead's *More Famous Trials,* 1928). Having learned the secrets of Exili, on his release Sainte-Croix joined Glaser in his traffic, and supplied the marquise with the means of killing, as she herself confessed, her father and two brothers, the motive being to acquire the family estate. She spoke of the poisons ironically as *les poudres de succession,* because they opened the way to the inheritance of property; their chief ingredient was arsenic. The marquise was beheaded in 1676 at the age of forty-two; the execution was witnessed by an immense crowd, who would have torn her to pieces had not the tumbril been well guarded. Victor Hugo in *Things Seen* describes the rack on which the marquise was tortured in the Conciergerie.

The crime of secret poisoning persisted until the end of the seventeenth century. One of the last poisoners for lucre in France was La Voisin, who was burnt alive in 1680.

The trade of poison selling for murder, though it still lingers in some parts of the world, may be said to be extinct in Christendom. What is much more, the occurrence of individual cases of homicidal poisoning has very considerably declined. The reason why this form of murder is sometimes imagined to be less rare than it actually is, will be found in the absorb-

ing human interest attaching to the persons and circumstances of every case, and the publicity given to it by the Press. Whatever credit belongs to moral influences for the decline, these are strongly reinforced by the constant advance of toxicology. The employment of new instruments of precision, and the accumulation of exact knowledge, are enlisted against the subtlety of the poisoner. Thanks to the contributions of chemistry, pathology, and pharmacology, close observation can identify the symptoms produced by poisons in the living, and the changes discoverable after death. It is even possible to obtain from an exhumed body the disclosure of secrets which have been buried in the grave for years.

CHAPTER II

HOW POISONS ACT

Toxicology is the knowledge of poisons—their sources, characters, properties, detection, and legal aspects, together with the symptoms and treatment of poisoned persons and the results found in fatal cases. Before discussing the action of poisons, both generally and in regard to particular substances, some definitions are desirable.

For what is a poison? This seems an easy question, but, in fact, the answer will vary with the point of view. In the *popular* sense it is a substance which is capable, in a small dose, of harmful or deadly effects; but there are recognised poisons which are only fatal in large doses, and, after all, the question of large or

small is relative. By a *judicial* dictum, "a poison is defined as that which, when administered, is injurious to health or life." Administration includes contact with, or introduction into, the living body, whether by the mouth, lungs, skin, rectum, or any other possible route. A sufficient *medico-legal* definition may be thus stated: A poison is a substance which is capable, when applied to, or received into, the system, of causing injury or death by its direct local action, or on entrance into, or convection in, the blood-stream, otherwise than by thermal, mechanical, or electrical agency.

There is no *statutory* definition of a poison, but several Acts are directly concerned with poisons. The Offences against the Persons Act, 1861, enacts that "whosoever shall administer, or cause to be administered to, or taken by any person, any poison or other destructive thing, with intent to murder, shall be guilty of felony. . . . Whosoever shall unlawfully and maliciously administer to any other person any poison or other destructive or noxious thing, so as thereby to endanger the life of such person, or so as thereby to inflict upon such person any grievous bodily harm, shall be guilty of felony. . . . Whosoever shall unlawfully administer to any person any chloroform, laudanum, or other stupefying or overpowering drug, with intent thereby to enable himself or any other person to commit any indictable offence, shall be guilty of felony. . . . Whosoever shall unlawfully administer to any other person any poison or other destructive or noxious thing, with intent to injure, aggrieve, or annoy such person, shall be guilty of a misdemeanour." Clearly, what the law stresses is the intention to kill or injure, and, without defining the word "poison," alternative terms are used—"destructive or noxious thing," "stupefying or overpowering drug."

A schedule in two parts of what are termed poisons

is included in the Poisons and Pharmacy Acts, 1868-1908, and subsequent Orders. Every substance, therefore, in these lists is legally a poison, and can be sold only subject to certain restrictions. The seller, other than a medical practitioner or veterinary surgeon, must be registered as a chemist. The box, bottle, or wrapper in which the poison is contained must be labelled with the name of the article, the word "Poison," and the name and address of the seller. Further, in the case of any substance in Part I. (which comprises the stronger poisons), (*a*) the purchaser must be known to the seller, or introduced by some person known to both parties; (*b*) the seller must enter in a special "poisons sale-book" the date, name and address of purchaser, name and quantity of poison, and the purpose for which it is required; (*c*) the entries must be attested by the signature of the purchaser. The regulations require that great care be taken in keeping poisons apart from other drugs, and in selling them in bottles distinguishable by touch from ordinary bottles.

The Dangerous Drugs Acts, 1920-25, and Orders, 1921-26, apply to the following six substances, all of which are contained in Part I. of the Poisons Schedule of the Pharmacy Act—viz.: Cannabis (known as Indian hemp), Cocaine, Diamorphine (heroin), Ecgonine (a derivative of cocaine), Morphine, and Opium. This legislation was enacted to curb the traffic in dangerous drugs and to check the vicious habit of self-administration. It regulates the importation, sale, and use of the substances named. Breach of the law is punishable by fine up to £1,000, and imprisonment up to ten years' penal servitude. For offences against the Acts a doctor was sentenced in 1926 to six months' imprisonment and a fine of £200; on appeal the sentence of imprisonment was quashed. Traffic in these drugs is an international problem; it is at present engaging the attention of a committee of the League

of Nations Assembly at Geneva, and compulsory limitation of the manufacture of dangerous drugs is being strongly advocated.

It will be observed that the same bodies are termed poisons in one Act and dangerous drugs in another. In fact, there is no sharp demarcation between the two terms. In varying circumstances the same substance may be a poison or a drug, according as its effects are harmful or curative; and, speaking generally, the question is one of dosage. Common salt, for instance, may be a remedy or a poison, although it is normally a food. One poison—arsenic—is subject to further restrictions. By the Sale of Arsenic Act, 1851-52, it is unlawful to sell arsenic to a person under the age of twenty-one, or to sell a less quantity than ten pounds, unless one ounce of soot, or half an ounce of indigo, is mixed with each pound of arsenic. For a sufficient reason the colouring matters may be omitted.

In regard to agriculture, if cattle are maliciously killed by poison, the offence is felony, punishable by penal servitude. Other statutes are the Poisoned Grain Prohibition and Poisoned Flesh Prohibition Acts, 1863-64, which forbid the placing of poisoned grain, seed, meal, flesh, or "other poisonous matters," in any exposed place, field, or plantation. In 1910 a farmer at Ongar placed poisoned grain on his land, with the result that over one hundred partridges and rooks were killed; a chemist who had prepared the grain with strychnine, and the farmer, were both fined.

Poisons exert their actions in several ways. They may damage any part, external or internal, with which they come into direct contact; they may enter the blood and impair or destroy its functions; or they may be carried by the blood throughout the body and disturb or stop the functions of tissues and organs. Thus they may be said to act directly, inter-

mediately, or remotely. It is usual and convenient to speak of the first group as acting locally; but more precisely the action of any poison is local, in the sense that it is exerted on the tissue which it selectively affects. Some poisons act in more than one of these ways, and this fact adds to the difficulty of classification on the basis of action, since the same poison may belong to two or more groups.

Corrosive poisons, while acting destructively on the tissues they touch, at the same time give rise to shock, through the nervous impulses flowing from the injured parts to the central nervous system, which may paralyse the brain and stop the heart and respiration. This is identical with what occurs in the case of an extensive burn, or mutilation of a limb. Some corrosives and many irritant poisons not only produce local injury, but they do still more harm after absorption into the blood.

For more than a century it has been known that poisons entering the body through the mouth or skin pass into the blood. Orfila was the first to demonstrate the presence of arsenic in the blood after it had been swallowed. Snake poison, if prevented from reaching the circulation by a ligature round a limb bitten by a snake, acts only locally and slightly, but on removal of the ligature its rapidly toxic action is exerted. When a poison is directly injected into a vein, it begins to act immediately, and the blood-current is so swift that animals have been killed in half a minute by the injection of cobra venom or prussic acid. Absorption by the lungs is rapid because of the diffusibility of gases and vapours and the extensive area of absorbing surface. Inhaled chloroform vapour is quickly absorbed, but when liquid chloroform is taken into the stomach it is only sparingly soluble and diffusible, with the result that absorption is comparatively slow. Speaking generally, dissolving a substance, or rendering it readily soluble, will hasten

absorption. Phosphorus in an oily salad is absorbed more readily than when given with water; the reverse is the case with white arsenic, whose solution is impeded by oils. Insoluble substances are non-poisonous; they act as foreign bodies.

The path and destination of poisons in the body, and the channels through which they are eliminated, can be traced. A remarkable fact is their selective action; though, when diffused through the blood, a poison has access to all the tissues, it has a predilection for some special tissue or organ. Thus strychnine acts on certain cells in the spinal cord, morphine on the brain, digitalis on the heart. A small quantity of one poison may have a toxic effect on all protoplasm throughout the organism, or a specific action on a special tissue, leaving the others unaffected; and even a general protoplasmic poison has a tendency to selective action.

Only in one of two ways can a poison affect the function of a tissue; it may stimulate or depress. The intrinsic cellular changes, physical and chemical, which produce physiological results, are as yet imperfectly known. However, it may be stated in general terms that the toxic action of a substance is related to its chemical composition and the chemical structure of the cells of the organism. Carbon monoxide, for instance, combines with the red colouring matter of the blood corpuscles to form a chemical compound, which, in sufficient quantity, is fatal.

In its main features, therefore, the action of a poison is sufficiently definite to allow of a general description, but it is subject to factors which influence the actual effects in different cases. Disregarding external conditions such as extremes of temperature, modifying factors relate both to the poison and to the patient.

In the first place, there is no substance which is poisonous irrespective of the dose; many recognised

poisons, given within due limits, produce beneficial effects and are used as medicines. At a lower limit they are inert; a higher quantity reaches a toxic dose; and a further increase, which would kill unless successfully overcome, constitutes a fatal dose. The term "fatal dose" in medico-legal usage applies to the smallest quantity of a poison which has been authentically recorded as having caused the death of an average adult. It should be added that not seldom persons have recovered from much larger doses.

An excessive dose may on occasion work its own cure by exciting prompt and profuse vomiting, with complete evacuation of the poison from the stomach. Oxalic acid is an example of a poison which causes death by corrosion and shock in a large concentrated dose, by depression of the heart in a small dose, and by depression of the central nervous system in a yet smaller dose. The operative dose of a poison which has been swallowed and absorbed into the blood is not the total amount ingested, but only the part present in the blood and acting on the tissues. Some may be expelled by vomiting, or rendered inert by treatment. Elimination by the excretory channels is also in progress. Hence, if absorption is slow and elimination rapid, the operative dose may not be very harmful. But where small doses are given over a long period, or larger doses at irregular intervals, chronic poisoning results.

The physical form of a poison may be gaseous, liquid, or solid. Absorbable gases which are inspired pass rapidly into the blood. The rate of absorption of a poison in solution will depend on the rate of diffusion from the part in which the poison is placed and on the solvent power of the blood in respect of the poison. Undissolved, but soluble, powders and solids remain ineffective in the stomach until they undergo solution; consequently, the most soluble substances are the quickest to act. The most important physical con-

dition of corrosives is the degree of concentration, to which their power of inflicting local injury is proportionate.

As regards the mode of administration, liquid and undissolved poisons are commonly received by the mouth, and fatal doses are estimated by this type. From the alimentary tract many have to pass through the liver, where they may be partially intercepted or modified before entering the general circulation. A material point is the presence or absence of food. Introduced on a full meal, the action of a poison will be delayed and mitigated, in contrast to its action on an empty stomach. Oily material distinctly delays the absorption of alcohol and of other poisons. After the contents of the stomach have passed into the intestines absorption is quicker and more complete.

Inhalation by the lungs is one of the quickest routes of entrance. Injection into a vein lodges the whole of the dose immediately in the blood-stream; organic arsenical compounds are administered by this route in measured dosage, thereby avoiding disturbance of the digestive organs. A poison inserted under the skin by a hypodermic syringe passes rapidly into the circulation, and a smaller dose (about one-fourth) will be fatal than when the poison is swallowed. Persons addicted to the abuse of morphine not infrequently have many puncture marks in their limbs, made by the hypodermic needle.

Poisons may be given mistakenly or wilfully in the form of a rectal enema; absorption takes place through the lining membrane, but usually at a comparatively slow rate, though some alkaloids are absorbed more rapidly than when swallowed; morphine and atropine are examples. The slowest route of absorption is from the intact skin; lead-workers, dye-workers, and other operatives are liable to poisoning from the substances handled in their occupation. Abraded skin is a rapid absorbent of dissolved poisons.

The state of health is an important factor. Persons in good health are better able to resist the action of a poison than those who are impaired by disease. To this rule there are exceptions; large doses of opiates are frequently given to persons suffering from acute pain and mania, without dangerous effects. Disease of the kidneys, by checking elimination, adds to the toxic effects of most poisons; and, naturally, diseases of the stomach, liver, and heart have a serious bearing on the chances of recovery from poisoning. Persons who have been deprived of food also are more likely to succumb.

In a fatal case it is sometimes a difficult problem to decide whether disease or poison was the cause of death.

The young and the aged are bad subjects for poisons. Children are extremely susceptible to opium; immaturity is not a complete explanation, since, on the other hand, they may take relatively large doses of belladonna without symptoms of poisoning. In old age the power of resistance diminishes, and degeneration of tissues is common. Poisons, therefore, are ill-tolerated.

It is well known that tolerance to the action of some substances can be developed by habit; familiar examples are alcohol, cocaine, and morphia. Immunity, however, is never complete, and fatalities from overdosage are not uncommon. Some persons' reaction to poisons is more or less than normal. Commonly it is a peculiar intolerance to particular poisons and drugs. Where this peculiarity exists small doses of a medicine induce alarming effects; in one person it is quinine, in another mercury, in others opium, boric acid, or antipyrin, or some other drug.

CHAPTER III

SYMPTOMS AND TREATMENT

Poisoning may be accidental, suicidal, or homicidal. In the first two forms decisive evidence is generally forthcoming and treatment can be promptly administered. The third form is more difficult to detect and deal with. Murder by poisoning is essentially a secret crime, which is perpetrated, as a rule, by gradual and intermittent methods, cunningly concealed, and calculated to stimulate natural illness. It is to be observed that the evidence of poisoning consists mainly of symptoms, but none of these are a monopoly of poisons. Symptoms are an expression of disordered function in the body, and may be caused equally by poison, disease, or injury. Consequently, the effects of poison may be mistakenly attributed to disease, or the converse mistake may be made. Thus opium poisoning is liable to be attributed to apoplexy, strychnine poisoning to tetanus, and poisoning by metallic irritants to gastritis. These considerations explain the discovery of poison in the body of exhumed persons whose death had been wrongly certified as due to natural causes.

The inference drawn from symptoms alone needs to be reviewed in the light of the existing circumstances, and, whenever possible, clinched by discovery of the poison. The act of poisoning may be a single one (acute), or a series spread over a period (chronic).

The symptoms of acute poisoning appear suddenly in a person till then in his usual health. This feature is conspicuous; on the other hand, there are forms of disease which are liable to a sudden onset; and poison may be taken by a person who is ailing at the time.

Again, in acute poisoning the symptoms occur soon after food, drink, or medicine has been taken. Most poisons begin to act within an hour of being swallowed; the symptoms, however, may be due to disease, and their invasion at the particular time a mere coincidence. When several persons have shared the same dish and are similarly affected at approximately the same time, poisoning is a reasonable presumption. It is improbable that several persons who have taken a meal together will be attacked suddenly about the same time with disease. Nor must the suspicion of poisoning be ruled out because symptoms appear only in one person; the poison may have been restricted to the portion served to him.

In chronic homicidal poisoning the symptoms are insidious because the poison is given in small doses, the intention being not to kill suddenly but to undermine the victim's vitality by degrees. The symptoms caused by an irritant poison resemble those due to disease of the digestive organs, and there may be no collateral evidence to arouse suspicion for some time. Doubts concerning the nature of the illness are bound to arise when the poison is administered at irregular intervals, causing anomalous symptoms which ebb and flow in a manner inconsistent with the natural course of the supposed disease. The doubts may be confirmed by the suspicious conduct of one of the persons in attendance.

Strong evidence of poisoning is furnished by the discovery of poison in the food or drink, or in the vomit. Above all, if poison is found in the urine of a patient suffering from suggestive symptoms, proof is established that the poison has been absorbed into the circulation and excreted. The detection and identification of the poisons are made by chemical tests. When chronic poisoning is suspected or proved, whether accidental or homicidal, it is a rule of the medical profession to have the patient removed from his dan-

gerous surroundings; in some cases treatment in a nursing home or hospital is advisable. As the cause of death is unnatural, in all fatal cases of poisoning information must be given to the coroner with a view to the holding of an inquest.

In the treatment of poisoning, the objects aimed at are summed up in the following rules: (1) Empty the stomach of the poison; (2) neutralise or render inert what cannot be removed; (3) counteract what has been absorbed; (4) aid elimination; (5) relieve the general symptoms.

Immediate application of the first of these is the rule for all non-corrosive poisons. The old-fashioned stomach-pump is obsolete, and evacuation is now best effected by the stomach-tube. The tube for an adult is of flexible rubber, half an inch in diameter and five feet long. In the outer end a glass funnel is inserted, or tube and funnel may be in one piece of rubber. Eighteen inches from the inner end a mark is made on the tube. It is passed over the tongue to the back of the throat and thence down the gullet to the stomach, until the mark reaches the teeth. Half a pint or so of warm water is poured in by the funnel, the latter being held above the patient's head. The tube is then tightly pinched between the finger and thumb, and the funnel is lowered below the level of the patient's stomach over a vessel; on removing the finger and thumb the contents of the stomach run out by atmospheric pressure. This process of siphonage is to be repeated until the water returns clean. When applicable, an antidote is left in the stomach. If the poison has been taken soon after a meal the tube may become blocked unless the stomach is first emptied by an emetic. Rubber gas tubing and a domestic funnel make an efficient apparatus for use in an emergency.

If a tube is not available no time should be lost in making a patient vomit. The best emetics are the simplest; table salt and mustard are always at hand;

either may be given, and repeated once or twice in a tumbler of warm water, the dose being a tablespoonful of salt or a dessertspoonful of mustard. Tickling the throat with a feather is a useful device for promoting vomiting. A good medicinal emetic is zinc sulphate, half a teaspoonful in a cupful of warm water.

For the purpose of neutralising a poison or rendering it inert, antidotes are invaluable. All corrosive poisons must be treated by this method, though in carbolic poisoning the stomach-tube is also permissible. Three classes of antidotes are employed—physical, chemical, and physiological. The first class has not much scope; an example is powdered charcoal, which absorbs alkaloids and minerals. Plain water acts as a diluent. Chemical antidotes are excellent. The mineral acids are neutralised by a weak alkali, conversely alkaline corrosives are neutralised by weak acids. Magnesium sulphate (Epsom salts), or sodium sulphate, combines with carbolic acid to form an innocuous substance. Morphine is rendered inert by potassium permanganate, or Condy's fluid.

The endeavour to devise a multiple physico-chemical antidote which would act as a general neutraliser of poisons is not likely to succeed. Murrell's compound, though of limited application, is advantageous in poisoning by arsenic, salts of zinc, digitalis, morphine, strychnine, and salts of mercury. It contains (*a*) saturated solution of sulphate of iron 100 parts; (*b*) calcined magnesia 80 parts, charcoal 40 parts, and water 100 parts. The iron solution is kept in a separate bottle, and added to the other mixture when required for use. It is given in repeated doses, a wineglassful at a time.

It may be surmised that antidotes may be discovered in the future, which will act chemically on poisons circulating in the blood. Physiological antidotes exert their action through the medium of the blood, where

they mingle with poisons already present and counteract them by producing contrary effects. This principle is known as antagonism; an ideal antagonist would be a drug which would overtake an absorbed poison, and neutralise it by acting on the same tissue in the reverse direction. So far such a consummation is unknown. Fortunately, however, there are drugs which can beneficially modify the symptoms produced by poisons, and are therefore physiological antidotes, though not to the limit of complete antagonism. Chloral partly fulfils the conditions by its antidotal effects in strychnine poisoning, but its action is not limited to the structures affected by strychnine. Atropine, within limits, is deemed an antidote to morphine; an anomaly of antagonism is illustrated by these two poisons, inasmuch as atropine is a better antidote for morphine than morphine is for atropine.

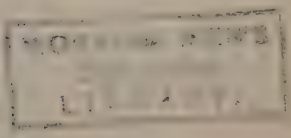
A striking example of poisons producing opposite effects, although not acting on identical structures, is afforded by atropine and physostigmine. Atropine quickens the rate of the heart-beat, dilates the pupil, and makes the skin and mouth dry by checking sweat and saliva. Physostigmine, on the other hand, causes slowing of the heart, contracts the pupil, and increases the secretion of sweat and saliva. Further researches in pharmacology may be expected to widen the scope of antagonism. At present the principle is not much used in actual practice.

The next principle to be considered is elimination of poisons from the system, which takes place chiefly through the excretory glands and the lungs. The kidneys, sweat-glands of the skin, and the liver play a prominent part in the process. In chronic poisoning by arsenic some of the poison is thrown out by the loss of hair, epidermal scales, and nails. Expulsion from the body by vomiting and purging operates by preventing absorption. The elimination by excretion begins very soon; some poisons are found in the urine

within five minutes of their administration. There can be no doubt that renal disease is a serious deterrent to rapid elimination. Medical treatment is directed to promote the activity of excretory organs.

In poisoning attended by great pain morphia is the most reliable anodyne; other symptoms are to be combated by suitable remedies. The urgent requirement is to bridge over the critical period until the poison is neutralised or eliminated. Artificial respiration is essential whenever the arrest of breathing is threatened. Warmth of the body must be maintained, and nutrient enemas may be required. Nothing more than mention can be given here to such highly specialised measures as the injection of warm saline solution, venesection, and the transfusion of blood.

Poisons are so various that a uniform plan of classification involves much duplication and inconvenience. In the chapters to follow a composite grouping will be adopted, based partly on the action, partly on the source, and partly on the form of poisons, as follows : corrosives; irritants; vegetable poisons; poisonous carbon compounds; gaseous poisons; food poisons.



CHAPTER IV

CORROSIVES

Corrosive poisons are either acid or alkaline. The members of this dangerous group differ among themselves but possess several features in common. They destroy any part of the body, external or internal, with which they are in contact; they can be neutralised or counteracted by antidotes; in treatment, the use of emetics is prohibitive, and for most of them siphonage by the stomach-tube is contra-indicated. The mineral acids in this group are sulphuric, hydrochloric, and nitric; the organic acids are carbolic and oxalic; while the alkalies include potash, soda, and ammonia.

The first of the acids, sulphuric, or oil of vitriol, is employed in some stage of most manufacturing processes carried on by chemical methods. It is a heavy, colourless liquid, and may be mistaken for other oily or syrupy fluids and accidentally drunk. It acts destructively by neutralising alkalinity, precipitating albumin, and dissolving proteins, the process being termed corrosion, and resulting in disintegration of tissues. Within the stomach the coats are corroded to a depth varying with the concentration of the acid and the duration of contact; the whole thickness of the wall may be burnt through, and the contents leak into the abdominal cavity. Sulphuric is the most destructive of the mineral acids. Invasion of the lining of the stomach to a slight depth is sufficient to corrode blood-vessels and cause hæmorrhage; by charring of the colouring matter the extravasated blood assumes a tar-like appearance.

The act of swallowing is attended by burning pain in the mouth, gullet, and stomach, as the liquid

flows over the lining membrane. Where it forms a pool in the stomach the pain is agonising, and soon extends widely over the abdomen and chest. Vomiting rapidly follows, altered blood and shreds of membrane being ejected. The vomit is acid and stains clothing and carpets on which it falls. The lips are excoriated, and the skin around the mouth shows brownish patches. There is intense thirst which is difficult to assuage, because even if fluid can be swallowed it provokes more vomiting. Respiration is obstructed by swelling of the mouth, and, since the movements of breathing increase the pain, they are restrained. Unless treatment prevails, the symptoms advance from bad to worse; continuous pain, the damage to the stomach, and the sense of impending death, depress the central nervous system, and a condition of collapse supervenes with coldness and failing pulse. In acute cases death may take place in less than an hour, or life may be prolonged for twenty-four hours. Consciousness usually remains until the end.

When the quantity of sulphuric acid taken is small and immediate treatment successful, the raw surfaces may slowly heal with the formation of scars. If so, the function of the stomach may be so impaired, or the gullet so narrowed by stricture, that surgical measures may be required to obviate death by slow starvation. One teaspoonful of vitriol has caused death. As the action of the acid is most energetic in the first few minutes of contact with the tissues, the treatment should be commenced without a second's delay. The chief aim is to neutralise the acid by an alkaline antidote. For this purpose nothing is superior to calcined magnesia, or milk of magnesia. Failing these, resort must be had to chalk, whitening, camphorated tooth-powder, or plaster and whitewash scraped from ceiling and walls. Soap is another alternative. Bicarbonate of soda must be given if it is the only alkali available, but it has the disadvantage of distending the weakened

stomach with carbonic acid gas. In the absence of chemical antidotes, the acid should be diluted by milk or water, in either case without stint. Emetics and the use of the stomach-tube are prohibited. The general treatment is directed to the relief of pain, maintenance of warmth of the body, and nourishment by enemas.

The next mineral corrosive, hydrochloric acid, is commercially known as spirits of salt or muriatic acid. It has the valuable property of being able to dissolve most of the metals, and is extensively used in industries. In England and Wales it is responsible annually for more fatalities than sulphuric and nitric acids put together; in 1925, 1926, and 1927 respectively the deaths numbered 77, 68, and 63; more than four-fifths of these were suicidal. The Alkali Works Regulation Act of 1901 was enacted to prevent the escape of hydrochloric acid into the atmosphere; thereby the public health has benefited, and vegetation as well. The fumes are injurious to man and destructive to cereals and fruit-trees.

The effects of swallowing hydrochloric acid, so far as the alimentary tract are concerned, resemble those caused by sulphuric acid. Hydrochloric acid does not as a rule cause external burns and stains around the mouth, though it may raise blisters; the lips are excoriated and swollen, and the tongue has an ash-grey colour. A striking feature is irritation of the air-passages, which is produced by inhalation of the fumes while the liquid is in the mouth, or when the respired air is charged with the vapour given off from acid spilt in a confined space. The mucous membrane lining the larynx and windpipe becomes inflamed, and there is much coughing. Breathing is quickened, the voice may be lost, and the face become blue from cyanosis. The respiratory symptoms may overshadow the gastric and precipitate the fatal ending. The same alkaline antidotes as for sulphuric acid should be

given. Steam from a steam kettle may afford some relief to the respiratory symptoms.

Nitric acid is known as *aqua fortis,* and colloquially by operatives as "akki." It is extensively used in the arts, and is indispensable in the manufacture of gun-cotton, nitro-glycerine, picric acid, and sulphuric acid. This substance has certainly been known for centuries; a death caused by it was recorded in 1593. The symptoms resemble those produced by hydrochloric acid, volatility being a common property of both acids. Points of difference are the yellow stains where nitric acid has been in contact and the formation of gas in the stomach. Yellow coloration of the skin is a characteristic feature resulting from a reaction which produces picric acid. The stomach is liable to be distended by gas which is evolved from organic matter by the acid; this condition adds to the pain and increases the difficulty of breathing. The treatment is the same as for hydrochloric acid. Persons exposed to the fumes from spilt acid should hold their breath and escape as soon as possible, and whitening or soap-suds should be thrown on the liquid.

Turning now to the organic group, carbolic acid, or phenol, is a colourless substance with a peculiar odour. To the tongue it gives a burning, sweetish taste. Unlike other acids, it does not redden litmus paper, but it combines with bases to form carbolates.

Discovered in 1834, this acid is of great historic interest because of its adoption in 1863 by Lister as the essential antiseptic of the Listerian system, on which modern surgery rests. It is familiar to all classes as a powerful disinfectant and poison. For sanitary purposes it is sold as a mixture of carbolic acid and other coal-tar products, in such preparations as izal, Jeyes' fluid, and creosote. Other phenolic substances of similar action are cresol and lysol. The latter is a soapy fluid made of cresol and linseed oil soap. The term "carbolic acid" applied to phenols in general is

the commonest liquid poison used suicidally in this country. In 1926 the number of deaths was 336, and in 1927 447. The great majority of the deaths were suicidal and due to lysol, a preparation which is widely used and easily bought.

Carbolic acid applied to the skin causes numbness; a strong solution makes a white stain changing to brown. Absorption through the skin may cause death; inhalation of the vapour is dangerous in a confined space. Its toxic action is both local and remote; locally it causes corrosion, remotely it paralyses the central nervous system. On swallowing the strong acid, burning pain is felt from the mouth through the gullet to the stomach, followed by vomiting, which is transient owing to the anæsthetic action of the poison. The angles of the mouth and adjacent skin are whitened. Absorption is rapid, and insensibility comes on early. The lips are blue, breathing laboured, the pulse weak, pupils contracted, and the skin cold. Death usually ensues within three hours, but it may take place in less than five minutes, or be delayed several days. One teaspoonful of carbolic acid has caused death; of lysol less than two teaspoonfuls is a fatal dose. In treating a victim, the stomach should be emptied and washed out. Epsom salts may be added to the ingoing water, and it is a useful first-aid remedy in the dose of a tablespoonful in a cup of warm water repeated in ten minutes. Emetics are usually of no avail, owing to the insensitive state of the stomach lining. If death threatens from failure of breathing, artificial respiration is indicated.

The other organic corrosive is oxalic acid, which with its compounds is widely distributed among plants; in combination with potash it occurs in rhubarb, sorrel, and the common dock. A pound of rhubarb leaf may contain twenty-four grains of potassium binoxalate, the domestic article called salt of sorrel or salts of lemon. In the arts the acid is exten-

sively used in calico printing and dyeing, and for cleaning leather and metals. The binoxalate is used in households for removing stains of ink and iron-mould from linen, and cleaning straw hats. It has frequently been taken in mistake for Epsom salts, with fatal consequences. The distinction between these substances can be made by the following easy tests :

Tests.	Oxalic Acid.	Epsom Salts.
Taste.	Sour.	Bitter, nauseous.
Reaction.	Very acid.	Neutral.
Heated.	Disappears.	No change.
Sodium carbonate	Effervesces.	White precipitate.
Ink.	Bleaches.	No effect.

Oxalic acid provides a link between corrosive and general poisons by combining the effects of both. In concentrated solutions it is a virulent corrosive, whereas in dilute solution the symptoms of corrosion are absent, and those due to the remote effects alone appear. Not uncommonly both sets of symptoms are present, the remote action being superadded to the immediate corrosion. As a corrosive, oxalic acid has much in common with mineral acids. An intensely sour taste is soon followed by burning pain in the mouth and in the stomach; vomiting is severe and continuous, and the vomit contains blood. The throat feels constricted, so that breathing and swallowing are difficult. Unlike what occurs in corrosion by mineral acids and carbolic acid, the skin around the mouth is not discoloured, but the lips are sore and swollen. Salt of sorrel is as poisonous as oxalic acid, and, like the latter, has often been mistaken for Epsom salts. Both the acid and the salt are in common use, and they have an attraction for suicides, of whom a con-

siderable proportion have been domestic servants. The mode of death is usually very painful. On the Continent these substances are not so familiar, and poisoning by them is infrequent. In England and Wales in 1926 thirty-three deaths were registered, and in 1927 forty-five; of these seventy-eight cases seven were accidental and all the rest suicidal.

The smallest known poisonous dose of oxalic acid is one teaspoonful. In most of the fatal cases death occurs within four hours; in many, within thirty minutes. Christison's graphic summary written a century ago holds good at the present day. "If a person," he wrote, "immediately after swallowing a solution of a crystalline salt, which tasted strongly acid, is attacked with burning in the throat, then with burning in the stomach, vomiting, particularly of bloody matter, imperceptible pulse, and excessive languor, and dies in half an hour, or in twenty or ten minutes, I do not know any fallacy which can interfere with the conclusion that oxalic acid was the cause of death. No parallel disease begins so abruptly and terminates so soon, and no other crystalline poison has the same effect."

The remote effects are exerted selectively on the nervous system and the heart. There is prostration, tingling and numbness in the limbs, twitching of muscles, cramps, and finally coma. The first procurable form of lime should be given at once; chalk, whitening, or lime-water will neutralise the acid. No form of soda or potash is permissible, as their oxalates are as poisonous as oxalic acid itself.

Of the corrosive poisons in the alkaline class, caustic potash and soda have much in common and produce similar effects. They are white solids met with in sticks which have been shaped in cylindrical moulds. They dissolve in water, forming strongly alkaline solutions. Their corrosive action is due to their powers of neutralising acids, absorbing water from the tissues,

and dissolving proteins; and, to a less degree, combining with fats to form soap. By these means they cause corrosion. They are prepared on a large scale for commercial purposes; pearl-ash, soap-lees, and washing soda have a similar action.

As with the corrosive acids, the effects of a caustic alkali are immediate in the form of burning pain in the mouth and stomach, whence it spreads over the abdomen. A soapy taste is perceived; vomiting soon occurs; the vomit is frothy and feels soapy; this simple test distinguishes an alkaline corrosive from an acid, and indicates the proper antidote to administer. Later the vomit is tinged with blood, and contains shreds of mucous membrane. Collapse ensues, with coldness of the skin and a feeble pulse, though, as a rule, death does not occur so quickly as with acid corrosives. In a large proportion of cases the primary effects are not fatal, and the raw surfaces may heal; but the scars and contractions are likely to narrow the gullet and derange the functions of the stomach, with consequent emaciation and starvation. Sir Charles Bell in 1816 described the narrow gullet of a woman who died of literal starvation twenty years after drinking soap-lees.

The poison requires to be neutralised without delay. Weak acids such as vinegar, lemon and orange juice, or tartaric acid, are the most readily available remedies. Olive oil and white of egg are soothing if they can be swallowed. In other respects the general principles of treatment apply.

Strong solution of ammonia, when swallowed, produces similar effects in the stomach to those due to caustic potash and soda. As it is differentiated from those alkalies, however, by its volatility, which renders it specially dangerous to respiration, it will be described in a later chapter among the gaseous poisons. Other substances which are frequently the cause of corrosion include chloride or butter of antimony, chloride of zinc (which is an ingredient of

Burnett's sanitary fluid), sulphate of copper, nitrate of silver, and bichromate of potassium and sodium. With regard to the manufacture of bichromates, operatives are liable to ulceration of the hands and within the nose. This condition is notifiable to the Chief Inspector of Factories.

CHAPTER V

ARSENIC AND OTHER INORGANIC IRRITANTS

Irritant poisons give rise to gastro-intestinal disturbance and inflammation, and may simulate the effects of natural disease of the stomach and abdomen. They are variously derived from animal, vegetable, and inorganic sources: typical members of the last-named class will be here described—namely, arsenic, antimony, lead, mercury, and phosphorus.

Arsenic surpasses all other poisons in medico-legal importance, because of its evil pre-eminence in secret poisoning. Its lethal power is a matter of common knowledge; and not seldom it figures in sensational trials. What is commonly termed arsenic is arsenious acid, or white arsenic. It is a white crystalline powder, fairly soluble in boiling water, but sparingly in cold, the solution being colourless, odourless, and almost tasteless. These properties facilitate its admixture in food or drink without arousing suspicion. Legally, arsenic cannot be sold in small quantity unless mixed with soot or indigo; this tell-tale coloration is a protection against homicide. Arsenic dissolves in alkaline

solutions with the formation of salts called arsenites, and such salts are contained in sheep-dips, weed-killers, rat-poison, and fly-papers. Arsenic has been mistaken for baking-powder, sugar, and like substances. Deaths have resulted from the application to the skin of violet powder mixed with arsenic; arsenical pastes applied to cancers are very poisonous.

Weed-killers are prepared from arsenite of sodium and may contain as much as sixty per cent. of arsenic, as in the Eureka weed-killer mentioned in the Grecnwood trial, 1920. Weed-killer was also referred to in 1929 at the inquests after exhumation on Mrs. and Miss Sidney, who had died from arsenical poisoning. A fly-paper contains five grains of arsenic, which is double the accepted fatal dose. Fly-papers were concerned in the Maybrick (1889) and Seddon (1912) trials. Absorbed arsenic is deposited in all the tissues—soft parts, bones, hair and nails; hence the possibility of detecting the poison in human remains years after death. Where the tissues retain arsenic the body is resistant to putrefaction. In the case of John Flannagan (1884), exhumed after three years, the body was so well preserved that the face could be identified. Arsenic is detectable by extremely delicate tests; either Reinsch's or Marsh's test can detect one-twenty thousandth part of a grain.

Arsenic may be conveyed into beer by glucose, used as a substitute for malt, when such glucose has been manufactured by the use of arseniferous sulphuric acid. During the years 1900-1901 there was an extensive epidemic of arsenical poisoning among beer-drinkers in England, with more than one hundred fatalities. The beers were found to contain one-quarter of a grain of arsenic per gallon, and the poison was traced to faulty sulphuric acid used in the manufacture. Natural waters in which arsenic is a constituent are those of Vichy and La Bourboule in France, and Levico in the Tyrol. Fish may be killed

in a stream receiving waste water from dye works where arsenic is used as a mordant. Wallpapers coloured with arsenical pigments may give rise to poisoning in two ways, either by detached particles floating in the air, or by the emanation of an arsenical gas.

Arsenic is much employed in the arts, while the industrial processes of smelting, taxidermy, artificial flower-making and dyeing are also sources of poisoning. Arseniureted hydrogen (arsine), formed by the action of hydrogen on arsenic, is an intensely toxic gas; it is a special danger of balloonists and those who fill toy balloons, and of workers in chemical laboratories.

In small doses, arsenic is a drug of established value. In recent years several organic preparations of arsenic have been introduced into medical practice for the destruction of protozoa, especially in the treatment of trypanosomiasis, syphilis, and malaria. These include atoxyl, salvarsan, and galyl. Remarkable cures on a large scale have been effected, but the treatment is not entirely devoid of risks.

The symptoms of acute arsenical poisoning are primarily those of gastro-intestinal irritation; in an average case they begin within an hour, and death may ensue within twenty hours. Faintness, and burning pain in the throat and stomach, are succeeded by vomiting, which is severe and continuous, and there is insatiable thirst. The pulse becomes feeble and irregular, and the patient dies collapsed. The symptoms often bear a close resemblance to those of cholera, and death may occur within three hours. Two grains have proved fatal. Chronic poisoning arises from the absorption of repeated small doses, and when the poison is taken intermittently the symptoms ebb and flow. Besides gastro-intestinal irritation, the effects include loss of flesh and strength, skin eruptions, numbness and cramp of the limbs due to neuritis, and

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progressive debility of the heart. In some persons arsenic seems to predispose to cancerous growths. Cases of industrial poisoning must be notified to the Chief Inspector of Factories.

Evacuation of the stomach by an emetic or the stomach-tube should be effected promptly. The best antidote is ferric hydroxide, made by adding carbonate of soda to tincture of iron. Barley water and milk may be given, and morphine to relieve pain. In chronic poisoning it is imperative to separate the patient from the source of supply.

A familiar salt of antimony, the next poison to be considered, is tartar emetic, which contains thirty-five per cent. of the metal. It is a gastric irritant producing effects both acute and chronic very like those of arsenic. The solution in water is odourless and has a metallic taste. It is seldom taken suicidally, but it shares with arsenic the ill reputation of being chosen by the criminal poisoner; given in small repeated doses it deteriorates the health, causing vomiting, loss of appetite, emaciation, and increasing weakness of the heart; hence it is liable to be mistaken for natural disease. Five grains of tartar emetic is a dangerous dose.

The case of Klosowski, *alias* Chapman, who was executed at London in 1903 for murder by antimonial poisoning, illustrates the possibility of deception by a secret poisoner. He compassed the death of three women with whom he had lived in succession, and the first two were buried on the strength of certificates that they had died from natural causes. The third woman was seen in her last illness by several doctors, and towards the end poisoning by an irritant was suspected, but too late for the necessary steps which would have turned suspicion into certainty, and made the proper course of action possible. The doctor in attendance declined to give a certificate of death and insisted upon a post-mortem examination, with the

result that a large quantity of antimony was found in the victim's body. The poison had been given as a solution of tartar emetic. The main symptoms, which continued off and on for three months in the final stage, recurred whenever the patient took drink prepared by the prisoner. After his arrest, the bodies of the other women were exhumed, and found to contain considerable quantities of antimony. This metal, like arsenic, has the power of delaying putrefaction. The first victim had been dead five years at the date of exhumation, yet "the face and head were those of a woman who might have been coffined that day from the appearance; even the eyes were unruptured" (Sir Thomas Stevenson). This remarkable case suggests two comments: it is never too late to make an autopsy; and the legal safeguards relating to cremation lengthen the arm of the law against criminals.

In the seventeenth century antimony was placed under a medical ban, and graduates in medicine in Heidelberg were required to take an oath never to use it. Tartar emetic has a great vogue to-day in the treatment of tropical diseases such as bilharzia. Because of its emetic property the poison is used in "drink-cures"; the nausea and vomiting which it causes become associated with the drink to which it is added, and aversion is the result.

No metal, next to iron, is more widely used in civilisation than lead, and none can compete with it numerically as a cause of illness and death. Operatives working in lead and its compounds in a great variety of pursuits incur the risk of poisoning by inhaling fumes and dust, or by swallowing particles, or through the skin. Smelters, potters, red and white lead workers, painters, enamellers, coachmakers, and plumbers are the most numerous classes liable to be affected. Legislation and factory reforms have greatly diminished the dangers during the last thirty years, as shown by the following figures: in 1899, 1,258 cases

of plumbism were notified to the Chief Inspector of Factories; in 1906, 632 cases; and in 1926, only 242 cases. Fatal cases numbered 47 in 1926, and 44 in 1927. Accidental sources of lead poisoning include water stored in lead cisterns, water, beer, and cider flowing through lead pipes, saucepans coated with lead glaze, newly painted rooms, and hair-dyes and cosmetics.

Lead poisoning may be acute or chronic. The acute form is rare and seldom fatal; it may be caused by acetate of lead, known as sugar of lead, or by Goulard water (ordinary lead lotion). Large doses act as gastro-intestinal irritants, causing a burning sensation in the mouth and throat, abdominal pain, vomiting, thirst, and collapse. In extreme cases death may be preceded by cramps in the legs, convulsions, and coma. Besides the routine treatment applicable to irritant poisoning, Epsom salts should be given to form an innocuous compound, and to act as a purgative.

Chronic lead poisoning, or plumbism, is the most frequent form of industrial poisoning. It is produced by the repeated reception of small quantities of the metal, which are eliminated slowly, and therefore accumulate in the body. Poisoning proceeds insidiously, and is often advanced before the nature of the illness is recognised. Three groups of symptoms are noticeable : colic, a blue line on the gums, and anæmia; neuritis and paralysis of the forearm, causing "wrist-drop"; and cerebral disturbances, advancing in some cases to insanity. Young people, particularly women, are specially liable to plumbism, and so are alcoholic topers. Personal preventive measures include strict cleanliness, no eating when at work nor until after washing, wearing of overalls and respirators where these are prescribed by the regulations; and no smoking when at work.

Mercurial poisoning may be caused by the liquid metal or one of its many compounds, especially corro-

sive sublimate (perchloride of mercury), which is an intense gastric irritant. Chronic poisoning (mercurialism) is a notifiable industrial disease, and may be caused by handling the metal, by inhaling it in the form of dust or fumes, or by repeated doses of the poison. The main symptoms are salivation, tenderness of the gums, tremors, and, in advanced cases, paralysis and mental disturbance.

The last poison in this group is phosphorus, but of the two kinds, yellow and red, only the former is toxic. It is a waxy substance, kept under water as it is inflammable, and on exposure to air it gives off luminous fumes with a garlic-like odour. Formerly "strike-anywhere" matches were tipped with yellow (sometimes called white) phosphorus, and these were a source of poisoning, the phosphorus being soluble in warm water; but since 1910 the manufacture and importation of such matches in England have been prohibited by statute, and now phosphorus poisoning is much rarer. Rat-paste contains the poison and is sometimes taken by suicides, with the result of a torturing death. Less than two grains is a fatal dose.

The earlier symptoms are those produced by an irritant poison like arsenic. The vomit has a garlic odour and glows in the dark, thirst is intense, exhaustion may ensue, and death within ten hours. More usually the symptoms subside, and there is a fallacious interval of two or three days, followed by a relapse and fresh symptoms; jaundice appears together with nose-bleeding, and other hæmorrhages, enlargement of the liver, prostration, and delirium; and death occurs within a week. The primary treatment consists in emptying the stomach, and giving weak Condy's fluid as an antidote.

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CHAPTER VI

VEGETABLE POISONS

Opium, Belladonna, and Strychnine

Vegetable poisons are very numerous, and may affect any organ in the body. None are more important than those which act upon the nervous system—brain, spinal cord, and motor and sensory nerves. Examples of cerebral poisons (opium and belladonna), and an example of spinal poisons (strychnine) will be considered in this chapter.

Opium gum is obtained from the Oriental poppy. It is a beneficent and powerful drug, merging with increased dosage into a fatal poison. Of its many alkaloids, the chief one is morphine, which composes about 10 per cent. of the gum, and is the active agent in opium or morphine poisoning. Heroin is a derivative of morphine. Opium and morphine enter into the composition of numerous preparations—laudanum and other tinctures, nepenthe, solutions of morphine, heroin, chlorodyne, and others. Quack remedies containing any form of the drug have been a public danger. Opiates are specially dangerous to infants; one drop of laudanum has proved fatal. Before the passing of the Dangerous Drugs Acts, three-fourths of all deaths from opium occurred in children under five years of age. Legal restrictions, and the introduction of other narcotics, have substantially decreased the mortality from opium poisoning. During the five years 1911-16, 338 deaths in England and Wales were attributed to opium or its derivatives; 173 deaths were suicidal, 2 homicidal, and 163 accidental. In 1927 there were 12 suicidal and 14 accidental deaths. Deaths of adults have been caused respectively by four grains of opium, one grain of morphine, and two teaspoonfuls of laudanum; but recovery has followed after

much larger doses. Bronchitis and disease of the kidneys increase the risk. In fatal cases the duration of the symptoms varies from one hour to several days; the average period is nine to twelve hours.

Morphia given by the mouth, and still more by the skin, is more rapid in action than opium, and its effects begin to appear in a few minutes; but whatever the form of the poison, the symptoms are the same. There is a brief stage of excitement in which ideas flow rapidly owing to apparent stimulation of the higher faculties, though, in fact, reasoning power is dulled and the trains of thought are not under normal guidance. The mental condition is one of self-satisfaction; languor ensues, and, when the dose is large, drowsiness, which lapses into deep sleep. In the earlier stages the person may be roused, but later no stimulus will avail. He lies comatose, with muscles relaxed, the pupils minutely contracted, the skin moist, the pulse weak, respirations slow and becoming irregular and stertorous. As the coma deepens the face becomes dusky, respirations slower and shallower, and the patient dies from asphyxia. To sum up, a stage of excitement precedes a stage of irresistible sleepiness, which passes into a third stage of profound narcosis.

Morphia is eliminated from the blood by the stomach and intestines. This fact has a significant application to the treatment. The poison also passes into the milk of nursing mothers. The first thing to do is to remove any of the poison remaining in, or returning to, the stomach; secondly, to prevent the onset of coma and cessation of respiration pending elimination of the poison. The first object is attained by washing out the stomach with a solution of potassium permanganate, and leaving some of the solution in the stomach; morphia is thereby oxidised and rendered inert. This lavage of the stomach should be repeated at half-hourly intervals, and should not be

omitted when the poison has been injected subcutaneously. For the second object mild methods of rousing the patient may be tried, but nothing approaching measures bordering on brutality. Later, artificial respiration is indispensable, together with inhalation of oxygen and warmth to the skin. Strong coffee also is beneficial.

The habitual self-administration of morphia and heroin by subcutaneous injection was practised by many persons after the war, but the practice has been checked by the Dangerous Drugs Acts. The habit is termed "morphinomania," or drug addiction, and it induces deplorable effects. The addict deteriorates morally, neglects his business, and is apt to become untruthful and dishonest. Physically, he loses appetite, suffers from abdominal pain, and emaciates. He is depressed and irritable, his sleep is disturbed, and memory impaired. Large and increasing doses are needed to keep up the desired effects; de Quincey took nine ounces of laudanum daily. The difficult process of cure is best carried out in an institution, where the drug can be diminished daily down to zero by the end of a fortnight. Unpleasant symptoms may be encountered, calling for skilled treatment, and relapses are common.

Classed with opium is belladonna, as its effects are also cerebral. This poison arises from the atropine group of plants, which includes *atropa belladonna* (deadly nightshade), *hyoscyamus niger* (henbane), *datura stramonium* (thorn-apple), and *scopolia Japonica* (Japanese belladonna). Their toxic action is due to the presence of the alkaloids atropine, hyoscyamine, and hyoscine (scopolamine). The two latter are less deliriant than atropine, but, generally speaking, their action is identical; they all dilate the pupil, and hence are termed mydriatics.

It seems probable that the poisoning of the army of Antony in Parthia, related by Plutarch, was caused by

atropic plants. In 1927 there were fourteen fatal cases in England and Wales, ten suicidal, four accidental. All parts of the belladonna plant are poisonous to man, but pigeons and rabbits are peculiarly insusceptible. The berries look like black cherries and attract children. Medicinal preparations are made from the root and leaves, as well as from atropine; an overdose of any of these is poisonous. Absorption may result from the application to the skin of belladonna plaster or liniment. Atropine eye-drops are a recognised source of poisoning.

Belladonna poisoning is poisoning by atropine; this alkaloid acts upon the brain and the ends of certain nerves, particularly those in secretory organs. The brain is stimulated, as shown by delirium, and then depressed. Symptoms come on soon and advance rapidly. The mouth and throat become dry from lack of saliva and mucus, hence speech is indistinct and swallowing difficult. The face is flushed, skin dry, temperature raised, pulse and respiration quickened. The pupils are widely dilated; and, as accommodation is paralysed, vision is indistinct and may be double. In a severe case the patient is excited, talkative, and presently delirious, the delirium being often cheerful and hilarious, or so violent as to need restraint. There are hallucinations, and imaginary objects are clutched at. Diseases for which the condition has been mistaken are scarlet fever, acute mania, and delirium tremens. The delirium subsides, sleepiness and exhaustion follow, passing, perhaps, into coma, with failing pulse and respiration, and death within twenty-four hours. On the other hand, a large percentage of cases recover, though for several days debility and dilated pupils remain.

Doses that have proved fatal are two grains of atropine, one teaspoonful of belladonna liniment, and fourteen belladonna berries. Treatment is directed to getting rid of any poison in the stomach by the tube

or emetics. Strong tea or tannic acid helps to render the poison innocuous. A weak solution of potassium permanganate is also useful. Threatening asphyxia is combated by artificial respiration.

Another vegetable poison acting on the nervous system is strychnine, a highly poisonous alkaloid obtained from the seed of *strychnos nux vomica,* or koochla-tree. The seed is about the size of a shilling, round, light brown in colour, and covered with silky hairs. Its texture is leathery, so that it is not easily pulverised. Strychnine was discovered in 1818. It is one of the bitterest substances in nature; a solution of one grain in a gallon—one seventy thousandth—is perceptibly bitter. It is an ingredient in medicinal preparations, and in Easton's and Fellowes' syrups. Vermin-killers, such as those of Battle and Butler, may contain ten to twenty per cent. of the poison. It has been dispensed in mistake for salicin and antipyrin, and, in a case known to the writer, for phenacetin, with fatal results. Two tabloids of Easton's syrup mistaken by a child for sweets caused death within an hour; the dose was not more than one-sixteenth of a grain. In the case of Palmer, the Rugeley poisoner, strychnine was the agent used in the crime. At that time (1856) there was no known test for the discovery of strychnine in the body, and Palmer was convicted entirely upon the symptoms preceding death, and especially the peculiar arching of the body after death.

The symptoms caused by a fatal dose appear quickly, and death usually takes place in less than an hour. On absorption strychnine acts selectively on the spinal cord, in such a manner that reflex excitability is heightened; in consequence, slight stimulations educe widespread muscular contractions merging into general convulsions. There are at first uneasy sensations, with twitching of the limbs, and a feeling of impending suffocation. Then suddenly a violent con-

vulsion occurs, the hands are clenched, and the body arched backwards so that it rests only on the head and heels. Breathing is impeded or impossible, the face becomes livid, the pulse quickens, and the pupils dilate. The convulsion lasts a minute or two, then the muscles relax and the patient lies exhausted, bathed in sweat. The spasm, however, returns in a few minutes, excited by a slight external stimulus, such as a current of air, the touch of a hand, a noise, or an attempt to drink. Since the higher centres of the brain retain their functions, consciousness remains, and mental anguish in the near expectation of death is added to the severe physical pain. Four or five spasms, with intermissions averaging ten minutes, may suffice to close the scene. Death is due to asphyxia during a spasm, or to exhaustion during an interval. If recovery is about to take place, the spasms diminish and the intervals lengthen.

In the treatment of strychnine poisoning, no time should be lost in controlling the spasms by the inhalation of chloroform. Then the stomach can be washed out with warm water until the washings cease to taste bitter. Tannic acid or potassium permanganate may be added to the ingoing water. If feasible, before the onset of symptoms the stomach should be emptied by an emetic. As an example of the value of chloroform, a case reported in the *British Medical Journal,* 1900, may be cited. A soldier took suicidally over four grains of strychnine; the characteristic convulsions ensued; he was put under chloroform and the stomach washed out. As spasms returned whenever the chloroform was intermitted, he was kept under its influence fifteen hours. He recovered. The best substitute in the absence of chloroform is chloral hydrate. To ward off threatened asphyxia artificial respiration must be resorted to.

CHAPTER VII

VEGETABLE POISONS (Continued)

Hemlock and Cocaine

Conium maculatum, or spotted hemlock, is a familiar plant in English hedgerows. The stem is green and marked with purple spots; the leaves are not unlike parsley leaves; the tapering root resembles a parsnip. All parts of the plant are poisonous and possess a mouse-like odour.

Nearly all the instances of poisoning in recent times have been accidental, usually owing to the mistake of supposing the leaves and roots were edible. In 1901 some boys from an industrial school were camping out on an island in the Firth of Clyde, and twenty-four of them were poisoned by eating hemlock; after prompt treatment by emetics they all recovered except one boy aged nine. Three children are recorded by the *Lancet* in 1851 to have been poisoned, one fatally, by blowing whistles made of hemlock stems; saliva in the mouth had received the poison from the moist and softened stems. All preparations of conium are sold subject to the restrictions of the Poisons and Pharmacy Act.

Hemlock is a depressant of all the *motor* nerves, inducing ultimately complete paralysis of the voluntary muscles. The effects begin in the nerve-endings, and gradually creep up the trunks of the nerves to the spinal cord, leading to absolute paralysis. The lower limbs are affected before the arms, and the nerves of sensation are much less impaired than the motor nerves, thus illustrating the principle of selective action by poisons. In a fatal case respiration is eventually involved, and death supervenes by asphyxia. The mind is usually clear until the end. The period between swallowing the poison and death seldom exceeds four hours. It was by drinking a draught of

hemlock that Socrates ended his life (399 B.C.) in pursuance of the sentence of the State. Because of its historical and human interest, and singular beauty, and because it is a genuine record of the lethal action of hemlock, the close of Plato's discourse, the *Phædo*, modified from Church's version, may be quoted here.

Plato relates how Socrates spent his last day in discussing with friends the question of the immortality of the soul, which he settled in the affirmative, concluding with these words: "A man should be of good cheer about his soul, if in his life he has renounced the pleasures and adornments of the body, because they were nothing to him, and because he thought that they would do him, not good, but harm; and if he has instead earnestly pursued the pleasures of learning, and adorned his soul with the adornment of temperance, justice, courage, freedom, and truth, and so awaits his journey to the other world in readiness to set forth whenever fate calls him. You, my friends, will set forth at some future day, each at his own time; but now fate calls me at once, and it is time for me to betake myself to the bath. I think that I had better bathe before I drink the poison, and not give the women the trouble of washing my dead body." After exhorting his friends to live in the doctrines he had taught, he impressed on them that at his funeral it was not Socrates they would bury, but only his body. As for that body, they might bury it as they thought right. Having bathed, he saw his children and the women of his family, and after giving them his last injunctions, he directed them to go away, and then returned to his friends. By that time it was near sunset, and presently the officer of the Eleven came, and, standing before him, said: "I know that I shall not find you unreasonable like other men, Socrates. They are angry with me and curse me when I bid them drink the poison because the Archons make me do it.

But I have found you all along the noblest, gentlest, and best man that has ever come here; and now I am sure you will not be angry with me. And so farewell, and try to bear what must be as lightly as you can; you know why I have come." With that he turned away weeping and went out. Socrates looked up at him and replied: "Farewell; I will do as you say."

Then he turned to his friends and said: "How courteous the man is, and how generously he weeps for me! But come, let us obey him; let the poison be brought if it is ready, and, if not ready, let it be prepared." One of his friends urged delay, as the sun had not yet set, but Socrates replied: "I think I should gain nothing by drinking the poison a little later but my own contempt for so greedily saving up a life which is already spent. So do not refuse to do as I say." After a time the man who was to give the poison entered, bearing it in a cup, and Socrates, seeing him, said: "You understand these things, my friend. What have I to do?" "You have only to drink this," he replied, "and to walk about until your legs are heavy, and then lie down, and it will act of itself." With that Socrates took the cup quite cheerfully, without trembling, and without any change of colour or feature, and looked up at the man with that fixed glance of his and asked: "What say you to making a libation of this draught? May I, or not?" The man replied: "We only prepare so much as we think sufficient." "I understand," said Socrates, "but I suppose that I may pray to the gods that my journey hence may be prosperous; this is my prayer; be it so." Saying this, he put the cup to his lips and drank the poison quite calmly and cheerfully.

When his friends saw him drinking they could no longer control their grief. Phædo covered his face, and his tears flowed fast at his misfortune in losing such a friend. Crito had gone away unable to restrain his tears; and Apollodorus burst into a loud cry, and

made everyone break down by his sobbing and grief, except Socrates himself, who said: "What are you doing, my friends? I sent away the women chiefly in order that they might not offend in this way; for I have heard that a man should die in silence; so calm yourselves and bear up." Then Socrates, having walked about until he said his legs were getting heavy, lay down on his back, as he was told. From time to time the gaoler examined his feet and legs, and, pressing his foot hard, asked if he felt it. "No," said Socrates. The gaoler then pressed his legs, and, going higher, showed the friends that Socrates was cold and stiff. Then Socrates felt himself, and said: "When the poison reaches my heart I shall be gone." He was already going cold about the groin, when he uncovered his face, and spoke for the last time. "Crito," he said, "we owe a cock to Asclepius; do not forget to pay it." "It shall be done," said Crito, "is there anything else you wish?" He made no answer to this question, but after a short interval there was a convulsive movement, and his eyes were fixed.

A vegetable poison which acts on *sensory* nerves is cocaine. This is an alkaloid obtained from the coca plant, *erythroxylon* ("red wood") *coca*, which is indigenous in South America, and has been introduced into Java and India. The alkaloid is a white crystalline powder; the hydrochloride readily dissolves in water. The properties of the plant were well known in the time of Pizarro (1532), and for centuries it has been esteemed by the Peruvians because of its supposed power to ward off the onset of hunger and fatigue during prolonged exertion. For this purpose it is chewed in the form of a paste of boiled potato mixed with the dry leaf. Cocaine remained neglected, however, until 1884, in which year Köller, a medical student at Vienna, discovered the anæsthetic effect of a solution applied to the eye, and thus inaugurated a revolution in ophthalmic surgery. Its application as a

desensitising agent to other mucous membranes soon followed.

To the tongue cocaine gives a bitter taste followed by numbness. This is due to its action of paralysing sensory nerves. A solution injected under the skin has the power of temporarily arresting the function of the local nerves to transmit the sensation of touch and pain, thus inducing local anæsthesia. Its use on these lines, however, has been abandoned in favour of less toxic but equally anæsthetic substitutes, especially novocaine. For the valuable practice of spinal anæsthesia, in which also cocaine was a pioneer substance, it has given place to safer anæsthetics. In the legal sense it is a dangerous drug as it is one of the six substances named in the Dangerous Drugs Acts; its inclusion in the list is accounted for by its seductive and sinister tendency to induce the habit of addiction to its use.

Cocaine enters the system from the stomach, or from beneath the skin when injected subcutaneously, or through mucous membrane, as when taken into the nostrils as a snuff. It is a stimulant to the central nervous system, first causing excitement with loquacity, and removing languor and dulness. With a fatal dose, the excitation increases and overflows to the spinal cord. The patient cannot keep still and is very talkative, his remarks being foolish and rambling; mental confusion, staggering gait, and general depression follow; the depression of functions deepens, affecting both respiration and the heart, and life is brought to a close by respiratory paralysis.

Chronic poisoning inevitably results from the continued daily administration of cocaine. The intermittent disturbance of the nervous system deranges the functions of all the organs. As toleration is soon acquired, to obtain the effects increasing quantities are necessary; and since, over and above its action on the nervous system, cocaine is a protoplasmic poison, the

health becomes deeply undermined. The symptoms include insomnia, hallucinations, digestive disturbances, and a sensation of insects creeping under the skin—"cocaine bugs." There are many deplorable instances of persons of fine intellect whose careers have been ruined by the consequential mental, moral, and physical deterioration of the cocaine habit. Administration is generally by hypodermic injection, or snuffing the powder mixed with boric acid—"white snow." At the trial in 1919 of de Veuille for the manslaughter of Florence Leonora Stewart, known by the stage name of Billie Carleton, it was proved that the latter habitually used cocaine as a snuff.

CHAPTER VIII

ALCOHOL AND CARBON COMPOUNDS

Intoxication, or drunkenness, is some degree of poisoning by alcohol. This condition has increased in social and legal importance because of the modern question of a person's fitness to be in charge of a motor vehicle. Alcohol is a narcotic, and has the direct effect on the nervous system of depressing its functions. The successive stages of intoxication are mainly three. First, the intellectual functions of self-control and critical judgment are impaired, so that speech and conduct become less restrained than in the

normal state. In the second stage functions of a lower level of the brain are disturbed; skilled movements are not well executed, and the special senses are blunted. The third stage is one of increasing lethargy, with mental and physical incapacity; in its progress the drinker sinks into a heavy sleep. Acute poisoning ending in death is rare nowadays.

A given quantity of alcohol does not produce the same result in all persons, nor even in the same person in all circumstances. Discrepancy between a "toper" and a moderate drinker is due to toleration induced by habit. In the case of any person, alcoholic effects vary with the percentage of alcohol, the rate of absorption, and fullness or emptiness of the stomach. "Under the influence of alcohol" is a very vague phrase; any quantity has some influence, and a single glass is taken with that purpose in view. There is no statutory definition of the word "drunk"; in the popular sense it is an obvious condition which presents no difficulty. The charge of being drunk in control of a car is decided on the evidence whether the accused was drunk in the legal sense; this hinges on the question whether he was so impaired by alcohol as to be unable safely to fulfil his legal obligations as a motorist. No single sign is sufficient; regard must be had to various details, including general appearance, demeanour, odour of breath, disregard of social conventions, slurring of speech, clumsiness in sitting down and rising, loss of balance in picking up a coin from the floor, and time sense relating to the previous few hours. It is not uncommon to find that a man who is the worse for drink is several hours out in his reckoning of the intervals of time between events of the same evening.

The next poison of the carbon class, chloroform, appears to have been discovered independently by Guthrie in America, Liebig in Germany, and Soubeyran in France, about 1830. Its adoption through

the advocacy of Simpson in 1847 as an anæsthetic for persons undergoing surgical operations has had an immense influence on the practice of surgery.

Except by misadventure during the inhalation of the vapour, death is very seldom due to chloroform poisoning. A few deaths are suicidal by drinking the liquid, very few by inhalation; murder by chloroform is extremely rare. In London in 1904 a man was sentenced to penal servitude for life for administering chloroform to his two children with intent to murder. The fantastic belief that the momentary application to the face of a handkerchief wetted with chloroform can induce narcosis is a crude superstition derived from works of fiction. An unexpected attempt of this nature might perhaps cause a nervous person to faint from fright, but sudden chloroform narcosis is contrary to all experience.

Chloroform deteriorates by the action of sunlight and air; the most harmful compound thus produced is phosgene. A special danger to avoid is the administration of chloroform in a small room lighted by gas; chlorinated vapours are set free, and are capable of poisoning persons who inhale them. Anæsthesia is developed in gradual stages. Among the earlier effects are excitation with struggling movements, confusion of ideas, and hallucinations. These subside into quiet sleep, passing into unconsciousness with relaxation of the muscles, loss of perception by the special senses, and loss of the sensation of touch or pain in all parts of the body. This is the stage of surgical anæsthesia; it may be maintained for hours by the regulated supply of the vapour and air. The danger of an excessive quantity circulating in the blood arises from depression of the respiratory centre and of the heart. Treatment is directed to oppose these tendencies.

With ether likewise, the chief interest of this substance lies in its use as a general anæsthetic, for which purpose it was first employed by Morton in 1846.

The narcotic effects are similar to those produced by chloroform. It is named in the lists of scheduled poisons applicable to Northern Ireland and the Irish Free State, but not in the English lists. Ether is drunk as an intoxicant in some parts of Europe, toleration of large quantities being acquired by habit. Chronic poisoning by ether-drinking leads to disturbance of the digestive organs and nervous system. Ether is very inflammable and cannot be safely used near a naked light.

Chloral, another carbon poison, is an oily, colourless liquid; on contact with water it forms chloral hydrate, a solid crystalline compound possessing a melon-like odour and a pungent taste. Chloral hydrate is a powerful hypnotic. Since its introduction as a medicine in 1869 it has caused many deaths, mostly accidental or suicidal. In spite of its smell and taste, it has been employed criminally by mixing it with beer or wine, with the object of stupefying the victim for a criminal purpose. In 1914, at Glasgow, a prisoner was sentenced to penal servitude for administering chloral hydrate to a man with whom he had been drinking and then robbing the man when he was unconscious. John Tyndall, the physicist, died in 1893 from an overdose.

Soon after taking a poisonous dose the individual is overtaken by sleep, which deepens into coma, with slow and laboured breathing, blue lips, and contracted pupils. The poison is a powerful depressant of the brain, spinal cord, and heart. As the temperature falls the skin becomes cold and the pulse increasingly weak. Chronic poisoning by chloral drinking is not so common a vice now as formerly, the more recent hypnotics having taken its place. Besides inducing weakness of the heart, dyspepsia, and skin eruptions, the habit may lead to disturbance of the mental faculties.

An hypnotic which has the advantage over chloral

that it does not depress the heart is sulphonal, occurring as colourless, tasteless crystals; it is sparingly soluble in water, more freely in alcohol. Its relative insolubility delays absorption, and as it is excreted slowly, its action may be prolonged into the next day. Its tendency to accumulate in the system renders it unsuitable for frequent use. Persons taking this drug without medical advice are liable to slip into the "sulphonal habit" and suffer from symptoms of chronic poisoning—namely, debility, dyspepsia, and mental and moral impairment. A single poisonous dose produces sleep, passing into coma, with failure of respiration. The coma may be protracted for several days. In sulphonal poisoning the urine may contain hæmatoporphyrin, an iron-free pigment set free by the action of the poison on the blood; the urine acquires a port wine colour, which is a signal calling for immediate cessation of the drug.

Trional and tetronal are other hypnotics similar to sulphonal in their properties. Both have caused fatal poisoning, the symptoms resembling those due to sulphonal. Another and perhaps the most popular hypnotic is veronal, or barbitone, a white crystalline powder, sparingly soluble in water, but freely in alkaline solutions. It is responsible for accidental poisoning far in excess of actual fatalities. Since the inclusion of this substance and its homologues in Part I. of the Poison Schedule in 1918, the annual number of deaths from their use has declined. In 1927 there were ten suicidal and ten accidental deaths.

Belonging to the same group of poisons are allonal, dial, luminal, and medinal. Veronal and all the allied compounds are too dangerous to be taken except under medical supervision. Medicinally, veronal produces normal sleep. Like sulphonal, it is eliminated slowly, so that with repeated doses it tends to accumulate in the system. In a large dose drowsiness merges into deep sleep and coma; the temperature is raised several

degrees, the lips are blue, the urine is red and contains hæmatoporphyrin, the breathing becomes laboured, and in fatal cases pneumonia is a frequent complication. Craving for the drug leads to its habitual use. This may produce tremors, reeling gait, thick and indistinct speech, and mental and moral degeneration. Sixty grains is a dangerous dose, but death has followed the taking of fifteen grains, and a dose of three hundred and sixty grains has been recovered from. Death may occur in twelve hours, or be delayed for two or three days.

Paraldehyde is a colourless liquid possessing a peculiar ethereal odour and a disagreeable taste. In a dose of one teaspoonful it is a powerful hypnotic, acting quickly, and the sleep is quiet and dreamless. It is eliminated by the lungs and kidneys, imparting its characteristic odour to the breath and urine. In large doses it produces insensibility resembling the narcosis of chloroform. Besides its action on the brain, it depresses the spinal cord and causes paralysis. In spite of its unpleasant taste, addiction to its use has been acquired, and toleration makes it necessary to increase the dose to sustain the effects. Chronic poisoning thus results, with symptoms similar to those of chronic alcoholism, and in some cases mental delusions.

Hydrocyanic or prussic acid (so called because first obtained from prussian blue) has a penetrating peach-like odour, and bitter taste. In respect of the smallness of dose, and its swiftly lethal power, it is one of the most deadly poisons known. It was discovered in 1782 by Scheele, whose death has been attributed to accidental inhalation of the vapour.

The substances amygdalin and emulsin are found in many plants, and the interaction of these in the presence of water yields hydrocyanic acid. Kernels of the peach, plum, and cherry, bitter almonds, and apple pips are examples. Both the oil and the essence

of bitter almonds are dangerous poisons. The acid is also obtained from the leaves of the cherry-laurel, a preparation of which is used in medicine; this was the homicidal agent in the case of Rex *v.* Donellan, 1781. Hydrocyanic acid is present in the liqueur noyeau; the acid floats at the top, and the first glass out of an old bottle has caused sudden death. It combines with bases to form cyanides; potassium cyanide, which is in common use by photographers and electroplaters, is a frequent source of poisoning. Sodium cyanide is used by fumigation to destroy rats and insect pests in ships and houses, a dangerous process unless due precautions are taken. Diluted hydrocyanic acid should contain two per cent. of the pure acid; Scheele's acid is twice this strength; French prussic acid is still stronger. As the acid is volatile, it readily escapes when the bottle is opened, leaving the percentage reduced. It is best kept in the dark in inverted amber-coloured glass bottles. Ratafia used in confectionery is an essence of bitter almonds freed from hydrocyanic acid.

Suicidal poisoning by prussic acid and cyanides is common, accidental is uncommon, and homicidal very rare. In the five years ending 1916, in England and Wales there were 233 cases of suicide by this poison, 34 cases of accident, and 1 of homicide. In 1927, 56 suicidal deaths were recorded. A tragical instance of an error in dispensing is reported by Arnold (*American Journal of Medical Science,* 1869). A pharmacist had put in a mixture for a child potassium cyanide instead of potassium chlorate, and the child died after the first dose; the chemist, however, convinced that he had made no mistake, to show the harmlessness of the preparation, drank some of it, and there and then died; while Dr. Arnold himself incautiously tasting the draught fell insensible and was unconscious for six hours. Half a teaspoonful of the diluted acid has caused death.

With a fatal dose symptoms begin in a few seconds; it is rare for them to be delayed more than two minutes, or for survival to extend beyond twenty minutes. Not seldom the victim is unconscious in a few seconds, and dead in less than two minutes. Prussic acid paralyses the brain and the heart, and prevents the cells of the body from taking oxygen from the blood (internal respiration). The most startling feature in the onrush of symptoms is the quick extinction of consciousness. The victim barely has time to move or to cry out before falling insensible in a convulsive seizure. The limbs become flaccid, pupils dilated, and pulse almost imperceptible. Respiration is spasmodic, with prolonged pauses increasing in duration until breathing ceases. In most cases life is extinct before medical aid arrives; but where the dose is not fatal within a few minutes there is a fair chance of recovery without treatment. When feasible, the stomach should be washed out with water, or a solution of sodium hyposulphite, or potassium permanganate. Inhalation of ammonia is useful, but the main stand-by is artificial respiration. In potassium cyanide poisoning the symptoms resemble those of prussic acid, but they do not begin abruptly. The fatal dose is five grains.

Another carbon compound, aniline, is also known as phenylamine and aniline oil. It is a colourless volatile liquid, with a vinous odour, and gradually becomes brown on exposure to air. It is the parent of many dyes, all of which possess some antiseptic action; many drugs used in medicine are prepared from it, antifebrin being a typical example. Aniline rapidly produces serious symptoms; it can exert its action through the stomach, lungs, or skin. Poisoning occurs among dye workers, rubber workers, marking-ink makers. Sucking an aniline pencil has caused serious results. Many instances of absorption through the unbroken skin are recorded; a number of infants

in a workhouse were affected as a result of wearing diapers stamped with aniline ink. Aniline poisoning, or "anilism," is a notifiable industrial disease, and a medical practitioner attending any case of the disease contracted in a factory or workshop is required to report the fact to the Chief Inspector of Factories. Such operatives are entitled to compensation under the Workmen's Compensation Act.

A characteristic effect of aniline poisoning is a bluish coloration which may be seen in the lips, lobes of ears, and tips of fingers and toes. This is due to coloured products of the poisons, or an alteration in the blood pigment, and not to cyanosis resulting from respiratory embarrassment.

Benzene, another of these poisons, is a volatile liquid obtained from coal-tar by distillation; it was discovered by Faraday. A synonym is benzole. It is used in the manufacture of aniline, and as a solvent for rubber and resins. Poisoning is produced both by the liquid and the fumes. Prepared from benzene is nitrobenzene, a yellow liquid known as artificial oil of bitter almonds, or essence of mirbane. Because of its peach-like odour it is used as a scenting agent. Industrially it is employed in the manufacture of high explosives, aniline, perfumery, and boot polishes. Operatives are liable to suffer from the fumes. The liquid is very poisonous, fifteen drops having caused death. Poisoning may be due to drinking the liquid, inhaling the fumes, or absorption through the skin. The vapour evolved from scented soap used in a warm bath has had grave effects, and liquid boot polishes in which nitrobenzene was a solvent have caused fatalities owing to absorption through the skin. In acute poisoning the most conspicuous sign is a blue appearance of the face, and sometimes of the whole body; the lips especially are darkened as though stained with blackberry juice. In the breath the odour of the poison is very perceptible. Anæmia, giddiness,

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dyspepsia, and other forms of ill-health occur in workpeople habitually inhaling the fumes.

The last of the poisons to be considered in this chapter is carbon tetrachloride, a volatile liquid having a quince-like odour. It is non-inflammable and is in common use as a fire extinguisher. A case was reported in 1926 of poisoning by inhaling the fumes from a fire extinguisher; the patient became pulseless and appeared to have stopped breathing, but recovery took place after artificial respiration for twenty-five minutes. Carbon tetrachloride is also used industrially as a solvent of rubber, resins, and fats. As a drug it has been extensively used in medicinal doses in the treatment of hookworm disease (ankylostomiasis). A teaspoonful is probably a safe limit for an adult. Either swallowed or inhaled it has an anæsthetic action like that of chloroform, but is decidedly less safe. It was formerly in use as a shampoo, but its dangerous properties have led to its discontinuance. A woman died from inhalation of the fumes while her hair was being shampooed in London with this substance in 1909.

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CHAPTER IX

GASEOUS POISONS

The gases treated in this chapter are substances in the gaseous form at ordinary temperatures. At the same temperatures many solids and liquids give off volatile bodies which are termed vapours; nitric acid, chloroform, and ether are of this nature. The hazard of inhaling poison gas was deeply impressed on the public mind during the Great War, and in ordinary civil life the subject is continuously growing in importance with the increasing use of volatile substances in modern industry. The number of fatalities from "gassing," already very large, is increasing, and should be reduced. Between gases and non-volatile substances there is the great distinction physiologically that the latter usually enter the body by way of the alimentary tract, whereas the former are inhaled. From the lungs absorbable gases pass into the arterial blood directly, and reach the brain almost instantly. The only gas which supports human life is oxygen; the inhalation of any other unmixed gas obstructs oxygenation of the blood and so tends to suffocate, and, beyond a certain limit, is fatal.

Noxious gases differ widely in their mode of action. Some are *simple asphyxiants,* in the sense that they are inert, and act solely by excluding oxygen from the lungs; nitrogen, which forms about seventy-nine per cent. of the atmosphere is an example. Carbon monoxide is a *chemical asphyxiant;* it poisons the blood and arrests the function of the red corpuscles as oxygen carriers to the tissues. Other gases—ammonia, for instance, act mainly as *irritants* to the respiratory membrane. A fourth group enter the blood by absorp-

tion from the lungs, and act as *remote poisons* on the brain and other organs.

Carbon monoxide is a very frequent cause of death; it is colourless, tasteless, and to most persons odourless, is slightly lighter than air, and burns with a pale blue flame. This poisonous gas is formed when carbon is burnt with a deficient supply of air. It is always a constituent of coal-gas, amounting to six per cent. or eight per cent. in various supplies, and the admixture of water-gas may double the percentage. In houses this is the main source of the gas, and the most common cause of poisoning. Poisonous quantities may enter the air from leaky gas fittings, open taps, smoky chimneys, slow combustion stoves, flueless geysers, faulty gas fires, smouldering blaize heaps, and lime kilns. It is a product of the ignition of explosives, and is a common cause of death of persons trapped in a house on fire. Exhaust fumes of motor-cars contain carbon monoxide in quantities which are dangerous in an ill-ventilated garage where the engine is left running. Tobacco smoke contains an appreciable amount, and large volumes of the gas are poured from the chimneys of a populous city. It is the cause of death from "after-damp" produced by the explosion of coal dust in mines.

If the respired air contains four parts of carbon monoxide in one thousand parts, death will occur in an hour; with high concentrations a few breaths will produce sudden unconsciousness; and a proportion of two per cent. kills in a few minutes. The pure gas is a deadly poison; two assistants of Christison after four inhalations became unconscious, and were recovered with difficulty. In recent years there has been a deplorable increase in the fatalities from gas poisoning. Suicide is easily effected by means of a gas oven, and this is by far the most frequent method of suicide in England. In 1917 there were 186 accidental and 165 suicidal cases of gas poisoning; in 1925 the numbers

respectively were 163 and 762; and in 1927 195 and 998. In France inhalation of the fumes of charcoal is a common mode of suicide.

The effects are entirely due to the combination of carbon monoxide with hæmoglobin to form carboxy-hæmoglobin. This deprives the blood of its power of conveying oxygen to the tissues, and causes oxygen starvation, and asphyxiation is the inevitable result. When one-fifth of the blood is saturated with the gas danger begins; a saturation of eighty per cent. is quickly fatal. The gradual penetration of carbon monoxide into the air attracts no attention to its presence, as it is unirritating and odourless. Coal-gas is perceptible by its odour, unless aspirated into a house through the ground at some distance from a broken gas main, in which event it loses its odour; such occurrences are not infrequent. A person breathing a diluted mixture of carbon monoxide and air is overcome insidiously; he becomes weak, languid, and drowsy, and though, perhaps, conscious of something wrong, is unable to shout or make an effort to escape; unconsciousness follows, the pulse weakens, and breathing fails. After death the face retains the hues of life, and there are rosy patches of skin on the trunk and limbs. Blood containing much carboxyhæmoglobin is a bright cherry-red colour, and, examined by the spectroscope, shows a characteristic spectrum.

The treatment of a person poisoned by carbon monoxide consists in removal to pure air, preferably warm, and, if breathing has ceased, artificial respiration. Whenever feasible, the manual method of artificial respiration is to be preferred to the use of mechanical apparatus, the patient lying face downwards (prone pressure method). If the victim's body is warm the procedure should be continued for at least an hour. The possibility of resuscitation from asphyxia due to gas poisoning (as from drowning or electric shock) depends upon the fact that the heart

may continue to beat for several minutes after breathing has stopped. Artificial respiration, therefore, should be begun without a moment's delay, for, once the heart has finally stopped, the last chance is lost. Classes for instruction in first aid cannot be commended too strongly. The inhalation of oxygen with the addition of five per cent. of carbonic acid hastens recovery. Suitable apparatus and competent first-aiders are available at the head police and fire stations of many cities and in large works. Chief reliance, however, must be placed on the application of artificial respiration by the first person on the spot. It is essential also to keep the patient warm. Persons who recover from acute gassing may take months before regaining their previous health. The after-effects may include impaired memory and mental dulness.

Coal-gas is a mixture of gases, chiefly hydrogen, marsh gas, and carbon monoxide. It owes its poisonous properties to the last named, which is present in varying percentages, and its effects resemble those caused by that gas. Another such poison, water-gas, is prepared by passing steam through red-hot coke. It is a compound of nearly equal parts of carbon monoxide and hydrogen, and the high proportion of carbon monoxide makes it a very dangerous poison. It burns with great heat and is therefore used in smelting ores. As it is devoid of odour, its escape into the air is undetected. Mixed with oil vapour, it gives a brilliant light, and, being produced at a cheap cost, it is added to the coal-gas supplied by most city gas departments and companies; the risk of carbon monoxide poisoning is thereby seriously increased to the consumers.

Carbon dioxide, or carbonic acid, is a colourless and odourless gas, heavier than air. It is often associated with carbon monoxide, as it is produced at the same time by explosions, conflagrations, lime-burning, and the like. It is found in mines, sewers, wells, and

caves, and, being a product of fermentation, it occurs in brewery vats. Incautious descent into such places has caused many fatalities. The notion that breathing can be safely carried on in a mixture of air and carbonic acid in which a candle will burn is erroneous. Air with twelve per cent. of carbonic acid will support combustion, but less than ten per cent. in the air will cause death. The candle test, therefore, is not to be taken as proving that a mixture in which a candle burns will support life. A man descended into a large vat after making the candle test; he was heard to call out, "There is gas here," and he instantly fell, and was dead when extricated. Carbonic acid accumulates in a deep well when the barometer is low, but with a high barometer pure air will flow down the well at a good pace.

In circumstances where workmen are liable to be overcome by any noxious gas, the provision of rescue apparatus should be obligatory. An unprotected would-be rescuer who goes into a gaseous atmosphere and succumbs gives no help and merely adds to the tragedy of the situation. The proper procedure consists in the wearing of a suitable mask or breathing apparatus, together with the attachment of a belt and safety line.

The effects of carbonic acid are sudden or gradual according to the percentage of the gas inhaled. A few breaths of a high concentration result in almost instant collapse and unconsciousness, with speedy death unless the victim is removed. When the amount is less it may cause giddiness, loss of muscular power, drowsiness, insensibility, and arrest of breathing. If exposure to the gas has not been too prolonged, artificial respiration in fresh air is a very hopeful treatment.

Gaseous poisons include a large group of irritant substances, differing among themselves in chemical and physical properties, but having in common the power of inducing inflammation in tissues they im-

pinge upon. Those which are not absorbed into the blood do not affect tissues remotely; their action is on mucous membranes and the skin.

When inspired, some act mainly on the upper part of the respiratory tract, others chiefly on the lungs, the selective action depending on differences in the solubility of the gases. A gas which is readily soluble in water attacks the first moist surface which it reaches; thus ammonia primarily injures the nasal passages and larynx, while nitrogen peroxide and phosgene (carbonyl chloride), being less soluble, exert their action deep in the lungs, where they induce pneumonia. The less soluble gases are therefore the more dangerous. The nose and pharynx may be severely inflamed without great danger or lasting damage; the local effects of injury to the larynx and trachea are more serious, but very dangerous results occur when an irritant gas reaches the air sacs of the lungs. The process is not a chemical corrosion, but essentially inflammation induced by changes in the cells of the surface insulted by the noxious gas. The inflammation is, in fact, a vital reaction to irritation of the tissues, and shows itself by redness and swelling of the inflamed parts and a plentiful flow of watery mucus. If the reaction stops at this stage recovery soon follows. In severe cases the lining of the larynx may become so swollen as to block the passage, and threaten or cause suffocation.

The lungs, however, are the seat of the greatest danger, and inflammation here is a menace to life in two ways. It prevents the due absorption of oxygen, and it also prevents the elimination of carbonic acid; in combination, these factors bring about asphyxia. Whether the sufferer will survive depends upon the intensity of the inflammation set up by the poison and his own inherent vitality. Another serious aspect of inflammation caused by irritant gases has to do with microbes. The normal barrier to bacterial infec-

tion is weakened by inflammation of the respiratory tract; and, consequently, a short exposure to a moderate irritant, while insufficient in itself to give rise to acute symptoms, may open the way to an infective bronchitis or pneumonia. The infections thus induced in industrial workers and the inhabitants of smoke-laden cities account for a great deal of sickness and mortality. The comparative death-rate from respiratory disease among workers in chemical factories in England is eight times as great as the rate for farmers.

The first of these irritant gases, ammonia, is a pungent suffocating gas, lighter than air; it is extremely soluble in water, the solution being intensely alkaline. Liquid ammonia is employed as a refrigerant in cold storage plants, and for the manufacture of artificial ice. A solid compound is carbonate of ammonia, which is used in preparing smelling-salts and *sal volatile*. Deaths have occurred from the inhalation of the vapour arising from a strong ammonia solution injudiciously applied instead of smelling-salts. The breaking of an ammonia cylinder in cold storage works envelops workmen in the fumes. In a recorded instance three men were exposed to the gas for three minutes; one died in fifteen minutes, another in two hours, and the third in five hours.

Sulphur dioxide is another example of an irritant gas. It is produced by the burning of sulphur, and is discharged into the air by the combustion of coal containing sulphur. It issues from volcanoes, and is destructive to vegetation. Exposure to the fumes occurs in many trades, but its intense pungent odour is a warning to the operatives. A small percentage in the air causes sneezing, coughing, and watering of the eyes and nose. Stronger concentrations set up bronchitis, or may cause rapid suffocation. Gas masks are protectives.

Sulphuretted hydrogen, known also as hydric sul-

phide, gives its malodour to rotten eggs. The gas is a product of the putrefaction of organic substances containing sulphur. Poisonings from this cause occur in sewers, tanneries, and glue factories. Like sulphur dioxide, it is found in volcanic regions, and is a natural constituent of many water springs, such as at Harrogate. Sulphuretted hydrogen is both an irritant and a remote poison, and probably also a blood poison. It is primarily an irritant, inhalation of a strong concentration causing almost instant death. When absorbed it may give rise to prostration, laboured breathing, and coma. In chronic poisoning there is inflammation of the eyelids and a predisposition to boils. Sewer-gas is a mixture of gases, sulphuretted hydrogen being the most dangerous. Men working in an ill-ventilated sewer have been rendered insensible by gassing, and have then been drowned in the sewage.

A typical remote poison, nitrous oxide, or laughing-gas, is at the same time probably the safest general anæsthetic known. It was discovered by Priestley in 1772, and first used for the painless extraction of a tooth by Colton in 1844. Absorbed into the blood, it acts on the central nervous system, producing a feeling of cheerfulness (hence its name laughing-gas), loss of sensation to pain, and insensibility. If given pure it acts as a simple asphyxiant as well as a narcotic; mixed with oxygen it can be inhaled for hours without asphyxial symptoms.

Many poisonous gases have been introduced into warfare; briefly summarised, they fall into three main groups. The earliest attacks in the Great War were made by gas released from cylinders and drifted into the trenches by the wind. Chlorine and phosgene belong to this first group of *lung irritants*. These gases cause irritation in the tissues of the lungs, resulting in various degrees of asphyxia according to the concentration of the irritant. (Phosgene [carbonyl chloride] is formed when a carbon tetrachloride fire

extinguisher is used in a confined place; fatalities have occurred from this cause.)

Lachrymators, the second type, are chiefly bromine compounds, and were projected in shells; they produce profuse watering of the eyes and smarting of the eyelids. Lastly are the *vesicants,* chiefly mustard gas or dichlor-ethyl-sulphide. This substance is a liquid which slowly vaporises, causing blisters and burns of the skin and inflammation of the eyes, nose, and air-passages. Efficient protection against all these poison gases was afforded towards the close of the war by respirators charged with charcoal, lime, caustic soda, and a permanganate.

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CHAPTER X

FOOD POISONS

Foodstuffs may be responsible for illness of any grade from slight to fatal. This is only what might be expected, seeing that foods are derived from a very wide and varied range of supply, and are subject to many stages and methods of handling, transport, storage, and preparation. No more than mention need be given to disturbances of digestion, which are attributable to wholesome food eaten at a time unsuitable to the person's state of health, or in excessive amounts.

The term food-poisoning in ordinary usage is applied rather loosely to two different conditions; on the one hand, food may give rise to ill-effects which

are correctly spoken of as poisoning; on the other hand, food may be the agency by which infections are imparted to the system by bacteria and their products. The latter group may more appropriately be placed in the class of food-borne diseases rather than poisonings. The list of well-known diseases transmissible by food of one sort or another includes tuberculosis, typhoid fever, scarlet fever, diphtheria, and parasitic diseases; and, in countries abroad, cholera, dysentery, and Malta fever. These are outside the province of toxicology, and are the concern of hygiene and general medicine. But the dictum of Celsus remains true that "all the parts of medicine are interwoven," and no sharp boundary can be drawn between toxicology and hygiene.

The most numerous class of what is still called food-poisoning comprises bacterial infections; these do not differ in principle from the recognised food-borne infectious diseases. Theories of a generation or so ago which applied the term "ptomaine" poisoning indiscriminately to outbreaks of illness traceable to food are of historical interest only as representing the best information of their time and the term is now deemed a misnomer. The present is a transition period in this subject, and the verdict "death from ptomaine poisoning" is becoming infrequent at inquests. Presumably in the future food-infection will cease to be considered a branch of toxicology. Ptomaines are chemical substances resembling vegetable alkaloids, formed in the process of putrefaction of animal proteins. Dead bodies, as shown by Pasteur, are invaded by microbes which are able to split up organic material into simpler degradation products, many of which are foul-smelling, and during the process ptomaines are formed; this occurs in a late stage, and they are not produced in harmful quantity until putrefaction is so far advanced that offensive changes are perceptible to smell, sight, and taste; the loathing excited by food

in such a state is a defence against its consumption. The theory that food containing ptomaines is a necessary or usual cause of poisoning is opposed to the fact that more or less decomposed foods are often eaten with impunity, and indeed from choice. "High" game and "ripened" cheese are examples. Moreover, there is a defensive mechanism in the cells of the liver and the epithileal lining of the gastro-intestinal tract by which the system is protected against alkaloidal and other poisons. Snake venom when swallowed is almost innocuous. The prevalent idea that putrefying food is a general cause of poisoning is not substantiated by evidence.

As the vehicle for poisoning, foodstuffs may be sorted into four groups, those which are (1) inherently poisonous; (2) infected with bacteria or their toxins; (3) contaminated with poisonous substances; (4) normal, but only harmful because of personal idiosyncrasy.

To take the first, some animals and plants in their natural structure are poisonous to man, and therefore are not foods in the proper sense, but they are sometimes eaten by inadvertence. Certain fish are of this nature, especially the puffers and balloon fish which haunt the coasts of China and Japan. The poison is mainly contained in the roe, and may kill by gastro-intestinal symptoms or paralysis of the heart. The barbel, sturgeon, and other European fish are reputed to be poisonous at certain seasons of the year.

Among plants which may be directly poisonous are some flowering plants and fungi. Of the former, the berries, seeds, leaves, and roots contain chemical poisons, and the victims are usually children. Such plants include monkshood, nightshade, foxglove, henbane, hemlock, laburnum, and privet. The list of poisonous fungi is very large; twenty-two species are known in this country. Probably the earliest case of mushroom poisoning on record is that of the family of

Euripides, who lost his wife, two sons, and a daughter, from that cause on some occasion when the poet was absent from his family. The fungi which account for most cases of poisoning are *Amanita phalloides* (death-cup) and *Amanita muscaria* (fly-fungus).

Amanita phalloides is the most frequent cause of plant poisoning; it is abundant; there is nothing in its taste to warn the eater; and a small piece may be fatal. It acts both as a digestive irritant and as a protoplasmic poison, causing degeneration of cells in the liver and nervous system. The symptoms begin after the lapse of some hours—namely, abdominal pain, vomiting and purging; prostration and jaundice supervene; in a day or two these symptoms may subside, or exhaustion may continue and end in coma in the course of four to eight days. *Amanita muscaria* contains the powerful poison muscarine. The natives of Siberia make a preparation from the dried fungus, which excites delirious intoxication. Its common name, fly-fungus, denotes that it is used as an insecticide; an infusion made by steeping the bruised fungus in milk attracts and kills flies. The symptoms are almost immediate; there is excessive sweating and salivation, giddiness, and difficulty of breathing. In mild cases removal of the offending substance by washing out the stomach may effect an early cure. In more severe cases nervous and mental disturbance is a prominent feature, with delirium and convulsions. In some respects atropine is a physiological antidote to muscarine.

An American physician, Dr. Prentiss, in 1898 reported the case of Count de Vecchie, an attaché of the Italian Legation in Washington, who shared a dish of mushrooms with his physician, and remarked on their delicious flavour. Within half an hour the count was completely prostrate, and oppressed by the fear of offending death; he developed blindness, difficulty in swallowing, and lost consciousness; violent

convulsions supervened, and he died on the second day. The physician also became extremely ill, and was unconscious for five hours, but in his case treatment resulted in recovery. The mushrooms proved to be *Amanita muscaria*. It is decidedly unsafe to eat mushrooms unless they are approved by competent persons to be edible. If mushrooms have been cooked and set aside it is unwise to eat them after they have been warmed up again.

As regards infected foodstuffs, the second group, every year there are outbreaks of poisoning affecting numbers of persons who have partaken of food from a common source, become ill at about the same time, and exhibited symptoms of a uniform type. These outbreaks occur most frequently in the summer, and in nearly all the instances which have been investigated the cause has been traced to infection of the food by bacteria and their toxins. In a large majority the organism is a member of the Salmonella group of bacilli, which contains the Gaertner bacillus (*B. enteritidis*), *B. ærtryche,* and *B. suipestifer*. They are able to multiply rapidly on foodstuffs, especially in warm weather, and their toxins resist boiling without losing their poisonous properties. The infection of food by bacteria is possible in several ways: (*a*) The food may be the flesh of a diseased animal, the bacteria being present before slaughter; (*b*) contact of the food with hands, knives, or receptacles soiled with the bacteria; (*c*) conveyed by vermin, flies, or dust acting as carriers of the bacteria.

An important feature is that the infected food may give no indication in regard to smell, taste, or appearance that it is otherwise than sound. There is always an incubation period between the meal and the onset of symptoms, the average interval being about eight hours. The variations are due to different proportions of bacilli and toxins in the food; preformed toxins will act quickly; bacilli need time to produce a poisonous

quantity of toxins. The constant symptoms are vomiting, diarrhœa, and abdominal pain; skin eruptions, feverishness, numbness and cramp in the limbs, and delirium may also occur. The mortality rate is low, not exceeding two per cent. of the persons attacked. The most frequent vehicles of infection are tinned meat, tinned salmon, made-up foods (potted meat, sausages, etc.) and milk and its products (cheese and ice-cream). Exposure of food in insanitary surroundings incurs a risk of infection. In an outbreak reported in 1923, over 400 persons suffered from eating infected ice-cream prepared in a dirty room opening into a yard laden with refuse. The bacillus was found in the ice-cream, and in several of the victims, one of whom died.

Another form of food-poisoning due to bacterial infection is botulism, of which the causative agent is the *Bacillus botulinus* (*botulus*—a sausage). Rare in this country, it is not infrequently a cause of outbreaks in Germany, Russia, and America. The organism is widely distributed; it has been found on cherries and olives on the tree, on leaves of plants, and on samples of earth both in Europe and North America. Poisoning arises not from the bacillus, but from the toxin, which is produced in foodstuffs suitable for growth of the organism, and for which an effective antitoxin is available. Fortunately, the toxin is easily rendered harmless by boiling, and therefore efficient cooking is an absolute safeguard against poisoning. Formerly, only sausages and smoked ham were blamed as the vehicles of botulism, but scarcely any class of food is exempt. After taking the infected food there is an interval of twelve to forty hours before the symptoms begin; these are referable to the nervous system, and comprise ocular disturbances, such as drooping of the eyelid, squint, dilation of the pupils, and impaired vision; partial paralysis of the tongue and throat; progressive weakness and heart failure.

The rate of mortality is high. The duration of fatal cases varies from two to twenty days. In 1918 in several English cities a number of cases of illness occurred with symptoms suggestive of botulism, but actually they were cases of "sleepy sickness"; somnolence is not a feature of botulism. In 1922 at a hotel near Loch Maree, Ross-shire, eight persons were poisoned by wild duck paste which proved to have been infected with the *B. botulinus;* all the eight died within a week.

Thirdly, food may be contaminated with adulterants, or preservatives, or with metals derived from containers, or with poisons added accidentally, wilfully, or by mischance. The adulteration of food is as old as commerce; for centuries in England there were regulations called the "Assize of Bread," imposing penalties on dishonest traders in food. The Food and Drug Act, 1928, applies the expression "food" to every article used for food or drink by man other than drugs or water. The stringency of the Act and the skill of analysts have eliminated poisonous adulterants from food; and the Public Health (Preservatives in Food) Regulations of 1927 forbid the addition of metallic or coal-tar colours, and restrict preservatives to small proportions of sulphur dioxide and benzoic acid. Danger from these sources has virtually ceased.

Canned foods stored in tins which have been sealed with solder may contain small quantities of tin or lead; poisoning from this source is very rare; this statement is the more significant in view of the immense extent to which canning is utilised for the preservation of food. An exceptional case of zinc poisoning, affecting two hundred men in an institution in Surrey, occurred in 1922. The metal was derived from galvanised iron pans in which fresh apples were stewed, and the symptoms, which were not severe, began directly after eating the hot apples. All the men recovered and went to work the next day.

Preparations of arsenic and antimony have been added to food in mistake for harmless powders, but, as was seen in the chapter on these metals, the cunning admixture to food of a slow or quick poison is the notorious method of the criminal poisoner.

Extraneous vegetable poison in food may be taken by mischance. An example is reported in the *Lancet*, 1921; three persons who ate stewed rabbit suffered from belladonna poisoning, owing to the animal having fed on the plant, and the alkaloid atropine becoming temporarily retained in the flesh.

Lastly, the peculiar sensitiveness termed idiosyncrasy, which exists in some persons in relation to drugs, also shows itself in a few people in the form of intolerance to particular foodstuffs. It frequently appears in infancy, is sometimes hereditary, and usually persists for life. As a rule, the intolerance is restricted to a single article of diet; it may be the white of egg, or cheese, or shell-fish, or strawberries. A person suffering from this susceptibility may be made acutely ill by eating a small quantity of the special food to which he is intolerant. Three groups of symptoms presented by different individuals are: Gastro-intestinal disturbance; skin eruptons, of which nettle-rash is the most common form; and attacks of asthma.

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APPENDIX

NOTABLE CASES OF POISONING

Name.	*Poison.*	*Date.*
Sons of the Prophets	Food ("Death in the Pot")	*cir.* 890 B.C.
Socrates	Hemlock	399 ,,
Cleopatra	Venom of asp	30 ,,
Britannicus	Prussic acid	A.D. 55
Brinvilliers	Arsenic	,, 1667
Donellan	Cherry laurel water	,, 1781
Bowyer	Hemlock	,, 1848
Palmer	Strychnine	,, 1856
Madeleine Smith	Arsenic	,, 1857
Pritchard	Antimony	,, 1865
Steele	Atropine	,, 1872
Bravo	Antimony	,, 1876
Chantrelle	Opium	,, 1878
Lamson	Aconitine	,, 1882
Neill (Cream)	Strychnine	,, 1892
Whitaker Wright	Potassium cyanide	,, 1904
Crippen	Hyoscine	,, 1910
Seddon	Arsenic	,, 1912
Armstrong	Arsenic	,, 1922
Sidney and Duff	Arsenic	,, 1929

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14. AUG 1936

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